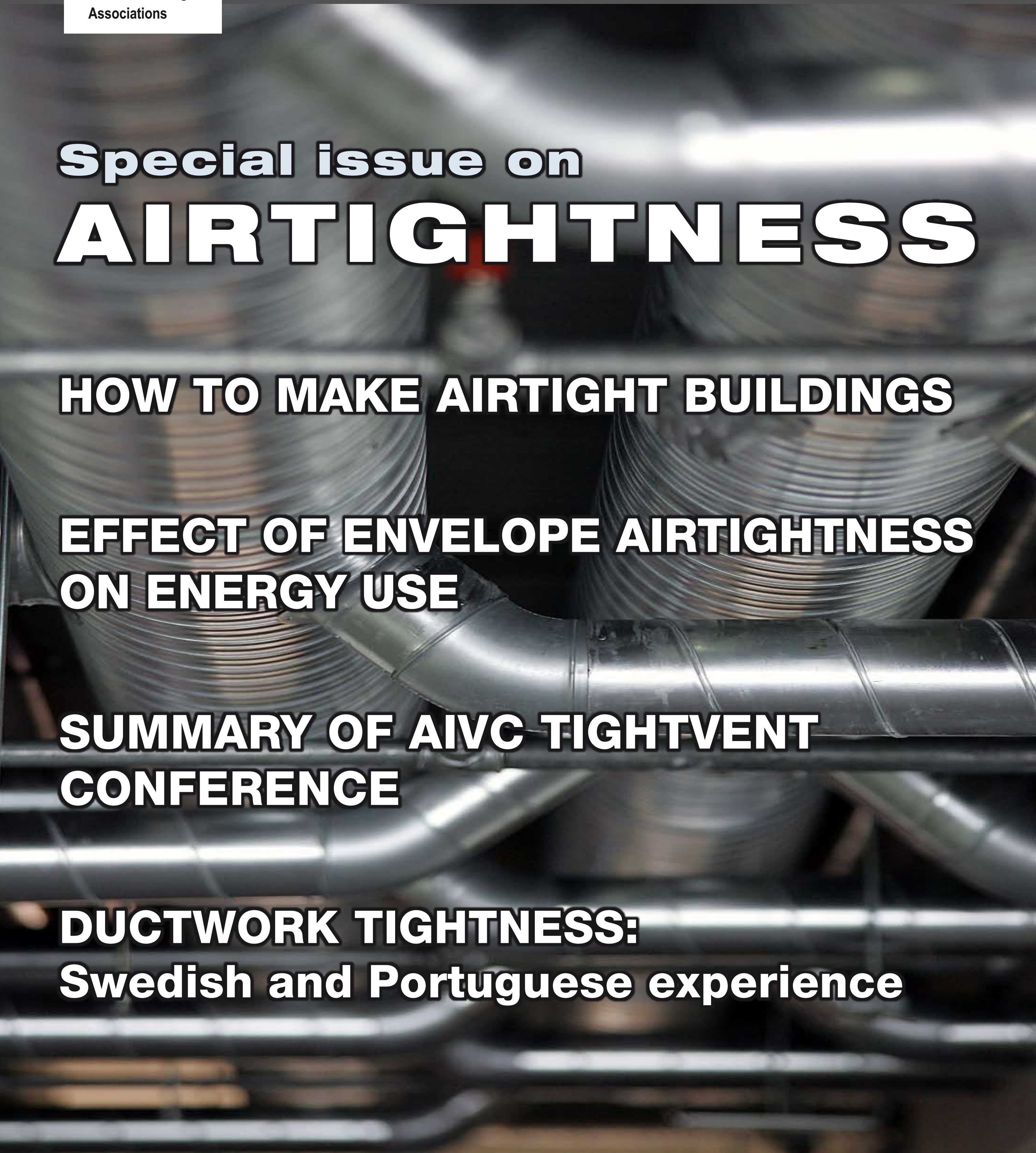
ISSN 1307-3729

REHVA

Federation of European Heating, Ventilation and Air Conditioning Associations

The REHVA European HVAC Journal

Volume: 50 Issue: 1 January 2013 www.rehva.eu



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Balmumcu, Barbaros Bulvarı,
Bahar Sok, Karanfil Ap.
Beşiktaş İstanbul Türkiye
Tel: 90-212-2758359
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Building and ductwork airtightness:
a critical factor for nearly zero-energy buildings


François Rémi Carrié *and* ***Peter Wouters***
Guest editors, AIVC/INIVE

Building and ductwork airtightness represents a key challenge for the building sector.

The 2002 Energy Performance of Buildings Directive (EPBD) already indicated the potential importance of airtightness. With the 2010 EPBD recast and its ambitious 2020 targets, there is even more pressure on these aspects since for most European climates and countries, good envelope and ductwork airtightness levels are necessary to achieve nearly zero-energy buildings.

Several studies report an energy impact of leaky buildings on the order of 10 kWh per m² of floor area per year for the heating needs in a moderately cold region (2 500 degree-days) and 0 to 5 kWh/m²/year for the ducts plus the additional fan energy use. There is a growing number of studies showing the significant impact of building and ductwork leakage in hot and mild climates as well. The general consensus from these studies is that attention must be paid to building and ductwork airtightness in nearly all climate regions of the European Union to meet nearly zero-energy targets.

How do we achieve this in practice? First of all, building and ductwork airtightness has to be seen as a part of the building system. Legitimate concerns for energy efficient ventilation, comfort, skills development and market uptake must be considered in a holistic approach, addressing both new and existing buildings. There are promising signals with regard to the measures taken in several Member States to encourage better building and ductwork airtightness. For example, there are over 10 countries, covering all climate regions of Europe, with active (and usually very active) networks of professionals specialized in airtightness issues. Also, the steps taken by some Member States to improve building and ductwork airtightness, including actions on regulation, financial incentives, training, control and awareness raising, look promising.

In 2011, the TightVent Europe platform (www.tightvent.eu) was launched with a strong focus on market change in airtightness. The large number of attendees at the two last AIVC-TightVent conferences, as well as the large range of countries and issues addressed during these conferences, linking airtightness, comfort, indoor air quality and market transformation, show the growing interest in this topic.

The 2012 AIVC-TightVent conference, held in Copenhagen, included three tracks specifically focussed on airtightness, ventilative cooling, and indoor air quality and health. As can be seen from the summaries presented in this issue, as well as from the initiatives presented by experts from various Member States, the route towards nearly zero-energy buildings has many challenges, but it is also a unique opportunity to investigate new paths for product development, construction methods, commissioning, and building operations. To seize this opportunity, the building sector needs to be both creative and reactive: sharing experience and knowledge is surely key to meet this need.

Over 160 persons attended the joint '33rd AIVC Conference' and '2nd TightVent Conference' in Copenhagen, on 10-11 October, 2012.

Summary of the AIVC-TightVent Conference 2012

Optimising Ventilative Cooling and Airtightness for Nearly Zero-Energy Buildings, IAQ and Comfort

The conference focused on ventilation and infiltration in nearly zero-energy buildings and more particularly on challenges and perspectives for ventilative cooling (the use of ventilation systems to cool indoor spaces), on the rationale and solutions for better building and ductwork airtightness, as well as on developments of ventilation requirements based on health. The programme included presentations of invited world-renowned and key experts as well as 75 papers selected from the call for abstracts for long- and short-oral presentations.

The conference was organized by the International Network on Ventilation and Energy Performance (INIVE) on behalf of the Air Infiltration and Ventilation Centre (AIVC) and TightVent Europe (the Building and Ductwork Airtightness Platform) with support from the VELUX group.

Per Heiselberg, **Willem de Gids**, and **Arnold Janssens** give here below a summary of the three tracks.

Visit **www.aivc.org** or **www.tightvent.eu** for additional information.

Next AIVC conference will be in Athens, Greece, 25–26 September 2013. It will be organised in conjunction with the 1st Venticool conference and the 3rd TightVent conference. More information will be soon available at www.aivc.org

Ventilation and Health track

Willem de Gids
VentGuide, the Netherlands

The ventilation and health related presentations and papers on the 33rd AIVC conference were very interesting. We could learn a lot from these papers. Many were presented results of international projects/initiatives such as:

- HealthVent "Health-Based Ventilation Guidelines for Europe"
- IAIAQ "Promoting actions for healthy indoor air"
- EnVie "Co-ordination Action on Indoor Air Quality and Health Effects"
- "Health and comfort in highly energy efficient buildings" Clear Up "Clear and resource efficient buildings for real life"

This summary synthesizes the papers and describes what we can learn from them. It is not a classic overview of papers but more a vision paper for future developments.

Why we ventilate?

Ventilation is often seen as the ultimate solution to all kind of indoor air quality problems. However ventilation is not a panacea for all indoor air quality problems: "just a little bit more ventilation and all problems are gone" does not always work. It is very clear that ventilation plays an important role in the control of a healthy environment in buildings. But to understand when, where and how much ventilation is a necessity is a question which is not easy to answer.

Let's first of all look to the functions and effects of ventilation:

- Supply of oxygen for breathing to survive in buildings
- Minimize exposure to hazardous contaminants to reduce health risks
- Minimize the nuisance of odors due to bio effluents to control comfort
- Dilution and transport of moisture to prevent from damp problems
- Creation of an environment in which people can perform in a optimal way
- Creation of an environment in which people feel thermally comfortable

The supply of oxygen, although an absolute necessity, is not an issue in buildings with the normally realized ventilation levels. On the other hand, ventilation can significantly affect comfort, health risks, damp problems and performance of people in buildings.

Health, comfort and performance are the key aspects for ventilation.

In the built environment the existence of ventilation is in most cases based on dilution and mixing processes. However, removing the unavoidable pollutant by local extraction is of course more effective. Displacement ventilation is the most effective mechanism to control ventilation flow and prevent from spreading of pollutants. Engineers often try to apply this so called "piston flow" mechanism, because of its effectiveness. But in practice due to disturbances, for instance, moving people and buoyancy driven flows, it is difficult to maintain and realize the flow patterns we had in mind during the design process.

In the Ventilation and Health track, there were sessions organized around Health and Demand Controlled Ventilation (DCV). Sometimes the results of the studies presented seem to conflict with each other. But analyzing the results more carefully, the conclusion appeared to be that the results of the studies were more complementary than conflicting. The main reason for this is the time frame which was considered in the studies, for instance short term exposure (a few hours) versus long term exposure (a few years)

Most important pollutants indoors

From the most leading international studies, it looks like that the main important pollutants which effect our health indoors are:

1. tobacco smoke (ETS)
2. ultra fine particles (UFP)
3. acrolein (unsaturated aldehyde)
4. formaldehyde
5. benzene
6. naphthalene
7. carbon tetra chloride
8. NOx
9. ozone
10. radon

For all these pollutants the general rule is: control the source therefore minimize their presence in the indoor environment. Only for that part of these pollutants which can be considered as unavoidable the exposure can be minimized with ventilation means.

ETS can be seen as an avoidable source in some buildings, while for instance radon should be minimized in most cases by special measures and not specifically and only by ventilation.

Carbon dioxide (CO_2) is not mentioned as an important pollutant at all, because it is a marker for bio-effluents of people. The level of CO_2 can be related to nuisance of odor. This was established since Pettenkofer in 1860 the basis for almost all ventilation requirements in buildings. Later Yaglou, Cain and Fanger were underlying this "odor nuisance driven" ventilation approach. Odor nuisance has not much to do with health, it is comfort driven.

There are also recent studies indicating that CO_2 itself might of influence to the cognitive performance of people. In case the performance of people is the most important parameter in rooms such as classrooms, lecture-rooms and even in some cases offices, CO_2 levels should determine more the ventilation level than nuisance and/or comfort.

When is ventilation needed and at what level?

This question is most important when discussing demand controlled ventilation. The only answer can be: It depends on the specific effect you are ventilating for on the place of consideration. The important question is:

"**What determines the ventilation flow at a certain moment on a certain or specific place?**"

For short term health effects for instance due to exposure of formaldehyde, which cause eye and throat irritations an immediate level of ventilation is required. For long term health effects (exposure during years) such as long term exposure to formaldehyde at very low concentration a yearly average ventilation of a certain ventilation level may the answer. Looking at moisture behavior in buildings, the processes of condensation, absorption, desorption and evaporation in relation to building fabric and furniture are typically processes of a number of hours so that diurnal average ventilation might be sufficient.

Looking into the performance of people in most cases again an immediate level of ventilation is required to perform well.

The time frame, the moment, the reason why one will ventilate gives the answer to the question what is the dominant pollutant at a certain moment on a certain place. Demand controlled ventilation in future should develop its control algorithms and control sensors in line with this view. In the field of CO_2 and VOC sensor control, some papers indicate that much progress has been made over the last years on sensor technology and sensor development.

Disability Adjusted Life Years

Many studies in this 33rd AIVC conference have tried to find a single expression of the effect ventilation might have on health. More and more common becomes the expression DALY, Disability Adjusted Life-Years. The DALY is more and more used as an indicator for health. It combines in fact three aspects:

- life expectancy
- quality of life
- number of people effected

With the aid of the metric DALY, all kind of decision can be made more objectively also in combination with cost on the basis of cost effectiveness.

Several speakers reported that, only for Europe, around 2.2 million DALYs/year are related to the indoor air quality in buildings. We can make progress in minimizing this problem by controlling the indoor air quality. Ventilation may contribute to that in a significant way in case we find effective solutions.

Ventilative Cooling track

Per Heiselberg
Aalborg University, Denmark

The current development in building energy efficiency towards nearly-zero energy buildings represents a number of new challenges to design and construction of buildings. One of the major new challenges is the increased need for cooling present in these highly insulated and airtight buildings, which is not only present in the summer period but also in the shoulder seasons and in offices even during occupied hours in winter. In most post-occupancy studies of high performance buildings in European countries elevated temperature levels is the most reported problem, especially in residences.

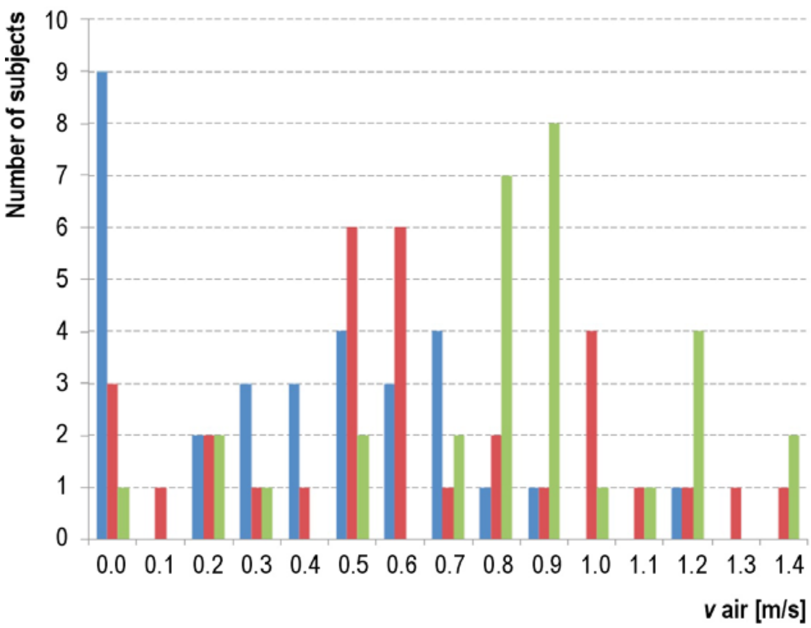
These new challenges were strongly reflected in the programme of the 33rd AIVC conference where about 30 papers and presentations in 6 sessions dealt with different issues related to ventilative cooling.

Performance Criteria

The first question to ask in the design of ventilative cooling systems is what are the performance criteria? What is considered as overheating and how can ventilative cooling be a solution? Research on different strategies to offset of warm sensation in high temperature conditions showed that increased air velocities can compensate and ensure comfortable conditions at higher temperature levels and that air fluctuations and turbulence intensity play an important role. But, the research results also showed significant individual differences in the preferred air velocity, which indicate that personal control is very important.

Prediction Methods

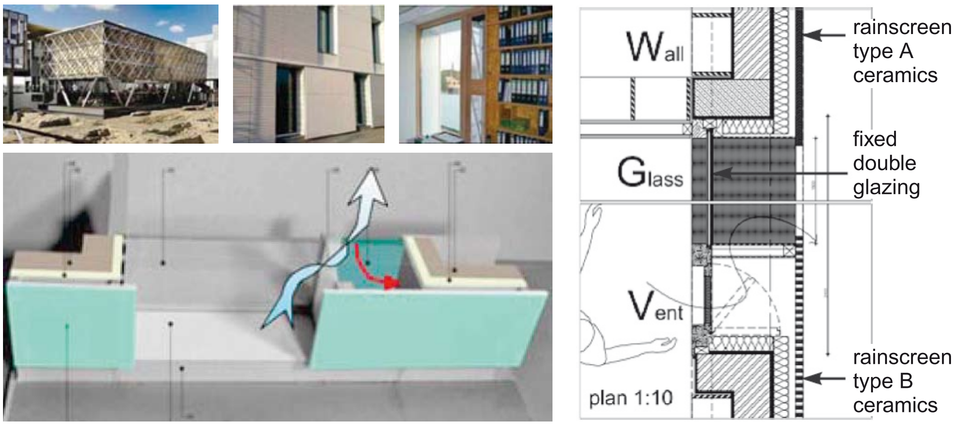
Prediction of energy use in residential buildings is often based on simplified monthly methods and is estimated for the residence as a whole. Averaging the need for cooling in both time and space underestimates the need for cooling. Excess heat in spaces exposed to solar radiation is considered to be distributed fully to other



Condition	t_o[°C]	RH %
A	26	50
B	28	45
C	30	40

Number of subjects choosing a certain velocity.
[Giulio Cattarin et al. AIVC Conference proceedings, pp. 8-12, 2012].

spaces and excess solar radiation during daytime is partly distributed to night time. Therefore, the need for cooling to ensure acceptable temperature levels in all spaces will be higher in reality. The analysis of the risk of overheating is often based on the calculated cooling need. Unfortunately, there is no correlation between the calculated cooling need with these simplified methods and the number of hours with elevated temperature levels. So, even if no cooling need is predicted and designers do not expect overheating problems, the number of hours with elevated temperature levels can be considerable. Several presentations dealt with these issues both from a more theoretical approach analyzing the energy balance and heat transfer processes within spaces in buildings but also different methods to predict Ventilative Cooling performance and the risk of overheating was presented.



The Nicosia Townhall where special façade vents were developed to realise ventilative cooling in the building. [Flourentzou et al. AIVC Conference proceedings, pp. 233-237, 2012]

Case Studies

A number of case studies on the application of ventilative cooling were presented. The case studies demonstrated ventilative cooling solutions both in residences, schools and shopping malls and in many situations considerable energy savings was obtained.

Several of the case studies highlighted the need for development of new technical solutions. One example was in the new Nicosia Townhall, where it was concluded that free cooling by night ventilation was the simplest strategy to keep comfortable temperatures, but using standard openings was not the best solution. In order to ensure better opening possibilities as well as protection from insects, dust and vandalism special façade vents were developed.

Conclusion

Ventilative cooling can be an attractive and energy efficient solution to avoid overheating of both new and renovated buildings. Ventilation is already present in most buildings through mechanical and/or natural systems and it can both remove excess heat gains as well as increase air velocities and thereby widen the thermal comfort range. As cooling becomes a need also outside the summer period the possibilities of utilizing the cooling potential of low temperature outdoor air increases considerably.

The outcome of the Ventilative Cooling track was that especially for residences there is a need to improve both the way we estimate the need and the performance of ventilative cooling as well as for development of new, off-the-shelf and competitive technical solutions.

Airtightness track

Arnold Janssens
Professor of Building Physics,
Ghent University, Belgium

The airtightness track at the AIVC conference consisted of 29 presentations organized in 7 sessions. In 3 sessions research work was presented dealing with various airtightness related aspects as requested in the call for papers. In 4 sessions invited presentations and structured discussions were offered to give an overview of some specific conference topics:

- Ductwork airtightness
- Quality and building airtightness
- Quality of domestic ventilation systems
- Philosophy and approaches for building airtightness requirements

In the following paragraphs a bird's eye view is given of trends and conclusions that appeared in the presentations and discussions in the airtightness track.

From airtightness requirements to quality assurance

A number of presentations showed experimental evidence of the fact that new buildings become increasingly more airtight, compared to buildings built in previous decades. This evolution is attributed to the strengthening of energy performance requirements, typically in European countries, and to innovations in construction practice. According to the European Energy Performance of Buildings Directive (EPBD) the influence of air infiltration on the energy use of a building is taken into account when assessing the energy performance. As a result, building designers pay more attention to airtightness in order to meet more severe energy performance requirements for new buildings. However, in some countries also explicit airtightness requirements are set in order to prepare the market for a change towards 'nearly zero energy buildings'. An example of this approach is the French RT2012 legislation, which requires the airtightness of all new residential buildings to be tested in order to show compliance to legal limits.

Several presentations showed that the specification of airtightness requirements alone is not enough to achieve good building airtightness in reality. When no quality framework is adopted, design intents for airtightness are not systematically met because of flaws and variations in workmanship. This was shown in a project in Greenland where a large number of identical flats in a building was tested and a standard deviation of 47% was reported. Creating airtight building envelopes entails profound changes in design and construction practice and requires careful planning of the overall building process. Therefore a number of quality management and training schemes were presented in order to master this process. Sweden has a long experience with the implementation of quality ductwork systems and has included quality requirements in the AMA specification guidelines, based on subsequent partial testing. In France regulatory quality management processes are operational for building airtightness compliance by constructors, based on self-declared testing of a sample of the housing production. Control tests have shown that these schemes are very effective in achieving good airtightness in practice (**Figure 1**). Good examples of

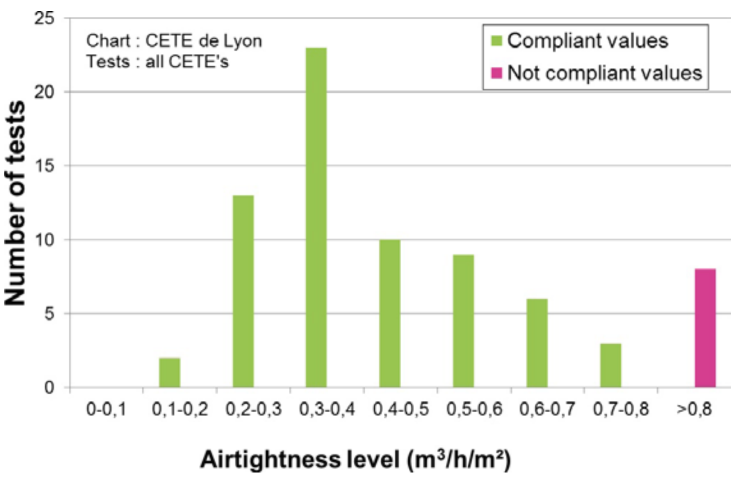


Figure 1. Results of control tests showing effectiveness of French quality framework for building airtightness compliance (85% compliance demanded, 89% compliance achieved). [Juricic et al.]

certification schemes for craftsmen were given by FLiB in Germany (Fachverband Luftdichtheit im Bauwesen), with guidelines for selection and installation of air barrier systems.

Air leakage testing and infiltration modelling

When airtightness requirements become more severe, also fan pressurization equipment and testing procedures to show compliance should allow to obtain reliable and repeatable test results. Several presentations were dealing with these issues. For testing single apartments in multifamily buildings different experimental procedures exist, and it is not always clear what one is measuring. A number of test results were presented quantifying the leakage distribution in apartments for different purposes: eg to assess the transfer of pollution between individual flats, or to assess the air leakage distribution ratio between internal and external partitions of apartments. A large-scale measuring campaign in high rise residential buildings in South Korea revealed that internal walls between flats often show the highest leakage (30-60% of total leakage).

A better knowledge of the air leakage distribution over the building envelope is also important to come to a more reliable extrapolation of fan pressurization test results at 50 Pa to air infiltration rates under natural driving forces (and related heat losses). While this extrapolation is typically based on rules of thumbs (the 'rule-of-20') or simplified steady-state models (Normalized Leakage), advanced simulation studies were presented to analyse the influence of uneven leakage distribution and unsteady wind conditions on air infiltration rates. Ultimately these studies should allow to develop more refined and accurate leakage models for infiltration heat loss assessment in high performance buildings.

IAQ and ventilation in airtight buildings

The fact that new buildings become more airtight is good news for the energy performance of buildings, but is also a reason for concern when indoor air quality and health issues are considered. In countries where residential ventilation traditionally relied on air leakage and on occasional opening of windows, such as in New Zealand, it is now found necessary to introduce reliable ventilation solutions to achieve acceptable IAQ and moisture control in new airtight houses. Even in countries where the installation of residential ventilation systems is part of the building code requirements, such as in most European countries, acceptable indoor air quality is not necessarily achieved. A number of multizone simulation studies were presented addressing IAQ performance in airtight houses. Although simulations showed that IAQ may improve with enhanced building airtightness, specifically for exhaust ventilation systems where designed air transfer is reinforced, the IAQ and indoor humidity achieved in airtight houses is sensitive to ventilation system design, sizing and installation errors.

However, some presentations discussed results of large-scale field studies showing striking evidence that installation quality of residential ventilation systems is typically insufficient. This was the case for studies performed in the Netherlands, Belgium and Estonia. Common shortcomings were insufficient supply ventilation capacity compared to design standards (in more than half of the investigated houses, **Figure 2**), increased noise levels in case of mechanical ventilation systems, and poor operation and maintenance. An overall conclusion was that together with increased building airtightness, more attention should be paid to ventilation system performance and installation quality, in order to guarantee healthy indoor environments. This requires a change of mind set, not only with building practitioners, but also with builders who should be more willing to pay the price for good quality ventilation systems.

Air Infiltration and Ventilation Centre

In recognition of the significant impact of ventilation on energy use, combined with concerns over indoor air quality, the International Energy Agency (IEA) inaugurated the Air Infiltration and Ventilation Centre in 1979. The AIVC is one of the annexes running under the ECBCS, Energy Conservation in Buildings and Community Systems, which is one of the Implementing Agreements of the IEA. The AIVC offers industry and research organisations technical support aimed at optimising ventilation technology. It offers a range of services and facilities, including comprehensive database on literature standards, and ventilation data. AIVC also produce a series of guides and technical notes. The Centre holds annual conferences and workshops. The operating agent of the AIVC is INIVE eeig (www.inive.org)

Figure 2. Air supply rates (average, P10 and P90) in the living room, master bedroom and other bedrooms in dwellings with balanced mechanical ventilation, at different control settings. The horizontal line gives the reference (minimum) level according to the Dutch Building Code (0.7 l/s/m2), (Boerstra et al.).

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Articles

Industry visions on R&D for better buildings in the future

The programme of the 33rd AIVC Conference began with a panel discussion facilitated by Kirsten Engelund Thomsen from SBI, Denmark.

REHVA Journal had an opportunity to have a short interview with the panellists, experts of leading companies in energy efficient technologies.

REHVA Journal presented the following four questions to the experts:

1. **What challenges do you see for the next 10 years (2020 objectives) and beyond (2050) in research and development in the building sector?**
2. **What are to your mind the major barriers to innovation e.g., legislative issues, calculation methods, costs, etc.?**
3. **What are the ways to explore to overcome the barriers?**
4. **What would be your suggestions to improve the quality of works (e.g. training and qualification of craftsmen)?**

Mrs. Lone Feifer
Strategic Project Director
VELUX Group

1 It is a fact that most of the buildings that have already been built represent a very large part of our future building stock. So I first and foremost believe that it is important to keep a long-term focus on finding and developing solutions that will ensure that the existing building stock lives up to the 2020 objectives and - further ahead - the goals for 2050.

Renovation of the current building stock represents a large economic potential and an enormous job creation potential. We are, however, faced with the challenge of scarce public funds. One answer to that challenge is to activate the large sums accumulated in private foundations and pension funds throughout Europe.

In terms of technology, the solutions are already here, but to meet the challenges of the future, we have to find a way to implement them in today's buildings. In other words a public demand must be created.

In that perspective it is important to not only focus on the energy efficiency of buildings, but to also secure a healthy and comfortable indoor climate with fresh air and daylight. One of the solutions is to promote the use and development of ventilative cooling in buildings.

The implementation of a number of mechanical solutions like air conditioning is constantly increasing. Those are solutions that use a lot of energy and do not necessarily provide the buildings with sufficient air quality. One of the major challenges is to secure that more environmentally and healthier solutions such as ventilative cooling is reflected in government regulations, promoted by the building industry and demanded by the public - the people who will be living in the low-energy buildings of tomorrow.

2 One of the biggest barriers to create more sustainable living in buildings is that promotion and implementation of the technology requires financing - financing of theoretical studies, test buildings and usability tests. This is also why it is important to promote a public awareness and demand for the solutions.

Building regulations also represent a barrier. Often they do not allow new technology to be implemented and they are often based or focused on quantitatively designed values instead of qualitative objectives. Strict rules and a one-sided focus on minimising energy consumption can create major barriers to the development of sustainable living in low-energy buildings.

3 First of all, we have to show and not only tell about the need for new ways of building houses. In the VELUX Group we've done this through the project Model Home 2020. In the project we've built six experimental low-energy buildings that are used by ordinary people. The houses have demonstrated the benefits of such technologies as ventilative cooling.

Through Model Home 2020 we learned that another benefit is that experimental building projects also encourage creativity and innovation because the focus on single technical values is redirected into looking at the building from more holistic and qualitative perspectives. This of course speaks highly for allowing a more experimental approach in today's building regulations.

4 In my opinion we need to focus on promoting simple solutions based on good building physics instead of over-complicated, maintenance-demanding systems.

In addition to training of craftsmen, there should also be increased focus on the installer's ability to advise the private buyer to make the right choices. In the ideal world the installers must have both relevant and updated knowledge on how to build low-energy buildings that also deliver a sufficient indoor climate with plenty of fresh air and daylight.

Claus Bugge Garn
Rockwool

1 In Europe we have app. 200 million dwellings, and we are constructing app. 1 million new dwellings per year (0.5% from total number). The new dwellings are mainly an expansion of the total building mass and not a replacement of existing buildings. Even if we from tomorrow only constructed nearly zero energy buildings; we would not reduce the energy consumption in buildings; but only maintain it at the current level

The focus, in order to fulfill 2020 and 2050 targets set by EU, thus have to be on how to make a deep renovation of existing building stock. We need to deeply renovate app. 2.5 – 3% of our existing dwellings per year; equal to app. 6 – 9 million dwellings. This is more than a doubling of the existing renovation rate; and the existing renovations are not focused on energy efficiency. This can only be done if new long-term financing mechanisms are put in place; such as the suggested "pay as you save" schemes.

These renovations will have to be done with craftsmen without expertise in energy efficiency; ventilation and indoor air quality; and with low education levels. By far most of the renovations will be done; without having a building engineer involved in optimizing the solutions.

We thus need to develop standardized "fool-proof" methods that can be installed by an untrained workforce.

2 The biggest barrier to innovation in the European construction industry is probably building traditions. The construction industry is a very conservative industry that do not "like to experiment"; especially within the private home sector. Building investments are very high; and often a once in a lifetime decision; and we thus do not like to experiment. This combined with the rather low knowledge level in the construction industry; makes it very difficult to introduce innovations.

3 History has shown that the most efficient way to control and change the constructions sector is via legislation (building codes). It is expected in the construction industry that a number of requirements have to be fulfilled when construction a new building or when making a major renovation. In general the construction sector strives to fulfill requirements.

4 There is no doubt that there is a strong need for training of craftsmen. The question is however how to get this training organized in an efficient manner. The construction industry consists mainly of very small companies; and in general a rather untrained workforce, often with language barriers due to many nationalities involved.

I believe that the best way to secure sufficient qualifications is by introducing authorization requirements for companies within the construction sector. Meaning that in order to bid for a construction job; the company needs to have an authorization. In order to have this authorization; the company needs to document that the craftsmen have received sufficient training.

Lars-Åke Mattsson
Lindab Ventilation AB

1 The challenge is very difficult and has a lot of approaches and a lot of stakeholders. The easiest part is to develop relevant products and systems that work and have a great impact on the energy consumption and at the same time gives an excellent indoor air quality with productive, healthy and happy people.

I see the following items as problems in the current situation and challenges for the future improvements:

- Building owners should have relevant information on the consequences of their decisions so that the final building with its systems meets the expectations.
- The current systems are not always sustainable and not based on life cycle cost analysis.
- The building systems are not always easy to operate, and may not operate on optimal way.
- There must be an organisation that is able to maintain and service the system and takes the responsibility of proper operation.
- If the system is broken there must be an organisation that can help the building owner and reset the system.
- Designers have to have more responsibility on the performance on system level so that that all technical equipment fit together and operate optimally in the building.
- The contractor has to be educated and informed by the designer so that systems are installed as designed and operate as intended.
- The politicians should create the business environment such that it is advantageous to meet the environmental targets.

2 The biggest barrier is the fact that supplier that has the cheapest product will win the project. The system of procurement is often very complicated and many involved can make money on a project that is right on the lowest limit of the regulation.

3 The most important issue is knowledge, all the way from the house owner to the politicians and the whole building industry. To educate everyone cannot be done by a single company. This can only be done by clusters of organizations like AIVC, Tightvent, REHVA, local branch organisations.

The certification like LEED, BREEAM are quite new systems that enable the house owner to buy a house with a level of predefined requirements without being an expert himself.

Another idea is to change the way of procurement so that the builder must take care of the operating costs the first five years or similar.

4 To improve the quality of the work is extremely difficult and has to be looked on from a holistic view and see it all the way from school, and the education material to certified installers and certified companies and associated salary systems. To make a reformation like this has to involve politicians, governmental school board, unions and employers confederation.

Proper building preparation for envelope airtightness testing

Proper building preparation is required before initiating an airtightness test. While this may seem surprising, HVAC systems often account for the most difficult part of the work. Taking this into consideration at the design stage of HVAC systems, however, can make the preparation easier.

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Introduction

When measuring the airtightness (or air permeability) of a building, there is a crucial question that needs to be addressed before starting work: **What is the objective of the measurement?**

This question, however, might be obscure for most people and may need refinement.

There are various reasons why one could measure the airtightness of a building:

- To check compliance with a building code or contract (e.g. $n_{50} \leq 2\ h^{-1}$);
- To check the effectiveness of new construction details (compared with other details in other buildings);
- To calculate the building's energy performance;
- To find and seal leaks;
- …

There are also different parts of a building that can be tested:

- The entire building;
- The thermally insulated part of the building;
- A new part of the building;
- One apartment in the building;
- All the apartments on a given floor;
- A block of offices in a factory;
- …

Hence, defining the objective of the test is essential for the operator who needs answers to practical questions:

- What part of the building is to be tested?
- What are the rules governing the test?
- What are the intentional openings in the envelope of this part of the building?
- What HVAC systems and other equipment are present in this part of the building?

All of this leads to the final question: What preparation does the building require?

Preparation in standards

Preparation of the part of the building subject to the test (hereafter called "the building") is specifically addressed in ISO 9972:2006 [2] and EN 13829:2000 [1], where different methods are described depending on the purpose:

- Method A (test of a building in use);
- Method B (test of the building envelope);
- Method C (test of the building in use) (not available in EN 13829).

In the current revision of ISO 9972 [3], the third method is replaced by a "free" method intended for specific purposes such as checking compliance with energy performance regulations. It thus opens up the possibility of preparing the building in accordance with a national regulation while still complying with the standard.

A point in common with all three existing methods is that all doors and windows in the building envelope must be closed. Another common point is the opening of all interconnecting doors within the building (note that the present exception for cupboards and closets will probably be deleted in the revision of ISO 9972).

Preparation of HVAC systems

In addition to these easily accessible openings and a number of secondary ones like post boxes or cat flaps, the main preparation work relates to HVAC systems.

First, all devices taking air from or removing air to the outside must be turned off: heating systems with indoor air intake, mechanical ventilation and air conditioning systems, kitchen hoods, etc. Since test operators generally are not HVAC engineers, instructions for operation should be available if needed.

It is important to understand that measuring a building's airtightness involves pressurising or depressurising the envelope typically at 50 to 100 Pa. Therefore measures must be taken to avoid diverting combustion gases or polluted air from their intended routes and venting them instead into occupied spaces.

In some cases, e.g. when open gas boilers in apartments are connected to the same chimney, it might be necessary to turn off the boilers of all apartments in the building, even if only one of them is being tested.

Second, all intentional openings in the building envelope dedicated to HVAC systems must be treated according to the measurement method. The three possible treatments are closed, sealed or open (**Table 1**).

When openings must be closed for the test, leaks in the closing system are taken into account in the global air leakage rate of the building. This means that the choice of HVAC components such as closable externally-mounted air transfer devices can be of great importance, not only with regard to ventilation but also with regard to the building's airtightness.

The same consideration could apply to smoke dampers or shut-off dampers for ventilation systems, cooker hoods and open fires.

When openings must be sealed for the test, their tightness depends on various factors:

- The skill and caution of the operator;
- The accessibility of the opening;
- Technique and material.

Remember that the highest pressure exerted on the building envelope during an airtightness test is approximately 100 Pa, which represents 10 kg/m². Thus, sealing works must be able to withstand this pressure. However, this is not always easy with large louvres for example (**Figure 1**).

Figure 1. Sealing a large louvre can prove to be a difficult task.

Table 1. Treatment of the intentional openings in function of the test method (ISO/CD 9972:2012 [3]).

Classification of openings	Method 1 Test of the building in use	Method 2 Test of the building envelope	Method 3 Test of the building for a specific purpose
Ventilation openings for natural ventilation	Closed	Sealed	Closed, sealed or open as specified
Openings for whole building mechanical ventilation or air conditioning	Sealed	Sealed	Closed, sealed or open as specified
Openings for local mechanical ventilation or air conditioning (intermittent use)	Closed	Sealed	Closed, sealed or open as specified
Windows, doors and trapdoors	Closed	Closed	Closed, sealed or open as specified
Openings not intended for ventilation	Closed	Sealed	Closed, sealed or open as specified

Sealing the mechanical ventilation systems is often necessary. There are three options:

- Sealing the air terminal devices;
- Sealing the air intake and exhaust;
- Sealing the main ducts.

Sealing the air terminal devices (ATDs) is often an easy job in single dwellings but can be very tedious in multi-family buildings or in office buildings for example. The most often used technique consists of removing the ATDs from the ducts and replacing them with rubber bladders (**Figure 2**). Alternatively ATDs can be sealed with adhesive tape.

Another option is sealing the air intake and exhaust vents, but this often requires access to the roof or the top of a wall, which might entail specific security measures.

The third option consists of sealing the main ducts just before or after the air handling unit (AHU). This, however, requires access to the inside of the ducts through the AHU or a partial dismantling of the ducts, work that cannot be done by the test operator (**Figure 3**). Proper inspection panels in these ducts might be very useful here.

To eliminate the need to seal the ventilation systems, shut-off dampers could be installed in the air intake and exhaust ducts. These of course should be sufficiently airtight when closed, in order not to degrade the results of the airtightness test. These dampers would also be useful when taking shelter in buildings is necessary, e.g. in the case of a large-scale outdoor pollution release.

It is also important to note that the airtightness of the ventilation ducts can influence the results of a building's airtightness test. During the test, air indeed could leak out of or into the ducts within the building envelope, and again leak into or out of the ducts outside the building envelope. Sealing the ducts precisely where they go through the building envelope could avoid this problem, but it is generally not feasible in practice. Making the ducts airtight is therefore recommended not only for ventilation purposes.

Chimney flues for boilers, air heaters or stoves are often open (or even closed in the case of stoves) during the airtightness test of the building. They, however, could be sealed if required for the test. In this case, access hatches primarily intended for soot removal can be very useful (**Figure 4**).

Figure 2. Rubber bladders can be useful for sealing ventilation ducts.

Figure 3. Sealing the main ducts just before or after the air handling unit is an option, but it generally requires dismantling the ducts.

Figure 4. Access hatches in chimney flues can be very useful if the flues need to be sealed for the airtightness test.

References

[1] EN 13829:2000 Thermal performance of buildings - Determination of air permeability of buildings - Fan pressurization method (ISO 9972:1996, modified).

[2] ISO 9972:2006 Thermal performance of buildings - Determination of air permeability of buildings - Fan pressurization method.

[3] ISO/CD 9972:2012 Thermal performance of buildings - Determination of air permeability of buildings - Fan pressurization method.

Performing intermediate checks and early-stage testing of airtightness

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Good building airtightness is now commonly regarded as an important prerequisite for both good energy performances, user comfort and service life of most modern buildings. Builders want to avoid the surprise of a poor airtightness measurement result in the finished phase of a new building. Repairing documented air leaks can then be a very costly experience and a complicated process.

This paper gives effective methods to overcome this problem, by sharing some good experiences from the process of avoiding pitfalls and achieving good airtightness of buildings.

Early-stage testing

Performing intermediate checks and early-stage testing of airtightness of the building envelope is becoming part of common practice in Norway. Locating and repairing leaks is at this stage is usually a very cost-effective task.

There are several approaches to early-stage testing:

TESTING REPRESENTATIVE SMALL PARTS OF THE ENVELOPE: In large building projects one may test representative parts of the envelope details that have been completed early compared to the rest of the project. The purpose of this is to gather experience that can be used further on other the parts of the project. This test is also useful as an extra quality assurance of as-built design, details and description of workmanship issues. This is especially helpful when the builder is confronted with building products or details that are new to the firm or to the industry.

One method of doing this testing is by defining and pressurizing a temporarily isolated representative zone, as shown in the **Figure 1**.

In this case, one measures the leakages from the test zone, including leakages from the temporary "tent". Designers

Figure 1. Temporary "tent" made from plastic foil, with a (red) blower door mounted. The amount of air that is sucked out of the tent by the fan in the blower door equals the leaking air that pass through the details of the façade being tested. A person inside the tent may easily detect air-leakages in the facade by just feeling with his hand along joints and details in question, if the air pressure inside the tent is kept at a lower level than the outside (around 50 Pa). This picture is from a new large building with passive-house ambition (n_{50}<0.6 h^{-1}).

and contractors may draw conclusions of good detailing, if one reaches good levels of airtightness. In the opposite case, one may not draw too strict quantitative conclusions, as some of the leaking airflow may come from the tent.

TESTING ZONES: Another approach is to pressurize a zone. These zones are often volumes of the building that are supposed to be airtight from other zones for other reasons too, like fire zones of a large building. In early stages of this kind of a building project, extra preparations are often required to insure airtightness from the other zones. Just achieving a pressure difference by use of a fan (not needing to read the measured leakages), and using a thermography camera, the technician may detect problems that need to be fixed for the rest of the project. **Figure 2** shows one example of a practical issue that had not been thought about in the design phase of the project: temporary anchoring of the

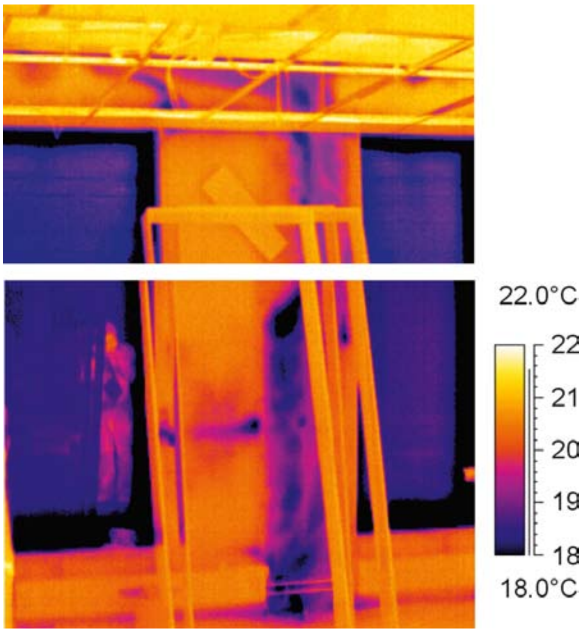

Figure 2a. Thermography from inside of construction shown in next photo.

Figure 2b. Leaky wind barrier detail, from anchoring of the outside scaffolding (Photos: Tormod Aurlien).

outside scaffolding. In this case, the design was immediately changed for the rest of the building project, and the already built part has been repaired.

WIND-TIGHT-LAYER TESTING: What seems like a Norwegian speciality is our relatively new emphasis on testing detached and semi-detached houses in early wind-tight-stage, often by using low-cost simplified equipment. A very large part of our population lives in these houses, and small firms usually build them.

Common experience from numerous airtightness measurements that have ended up with high air permeability levels, shows that trying to repair leaks on the inside often is nearly fruitless. A report often has thermograms pinpointing the leaks, but the technician only detects where the leakage airflow enters the inside of the building, not its source. The source may be somewhere in the outer wind-tight layer. Once the air has leaked in from the outside, it is easily distributed through cavity constructions that are filled with highly permeable insulation. As constructions have become thicker, often with the vapour-barrier being placed at a defined distance from the surface materials, it has become increasingly more challenging to detect the flow paths using infrared cameras or other detection techniques.

A natural response to this has been to perform airtight-measurements in the stage where the outer layer is complete, doors and windows are in place etc, but before insulation is placed from the inside and covered. Leakages are readily detected in this stage, by just feeling with the hand, having an inside under-pressure through use of the measuring fan. Furthermore the repair of these leakages is very cheap and easy.

We know of three measurements in this early wind-tight-stage being performed in the 80's in Norway. A later similar measurement that took place in 1998 caught great interest.

An initiative from The Norwegian Homebuilder Association soon led to simplified equipment being designed and spread to the market of their members in the building industry (**Figure 3**).

The initial philosophy was to just create a pressure difference between the building and the outside (exceeding around 30 Pa and possible to feel by hand on foils

www.Flexit.no
300 – 1 500 m^3/h @ 50 Pa

www.villavent.no (Systemair)
Small < 500 m^3/h
Medium 500 – 1 500 m^3/h
Large 1 500 – 3 000 m^3/h
@ 50 Pa

Figure 3. Simplified Norwegian equipment for airtightness measurement of smaller buildings.

etc. being tight). If the craftsman using the fan failed to achieve any pressure difference across the wall, then his job was to find the leaks and repair them, until a pressure could be detected. This simple approach was very good! The project caught on, and it soon evolved into having some quantified results coming out of the process too.

Response from craftsmen

Doing airtightness testing on a more regular basis has been met with a bit of scepticism by some building firms. On the other hand, a very common reaction by skilled craftsmen, is that they very much appreciate being valued for the effort that they put into good craftsmanship and reaching technical goals, like airtightness; not only being valued for their effort towards the aesthetic finish. It is nice being told in forehand in the project that measurements are planned, though. Being given the tools to perform these checks by oneself is even nicer. This last point has been an important reason for development of the simplified-method testing: the possibility for the builders to perform testing themselves.

An important additional argument for performing these simplified-method tests is that airtightness testing requires being on site on exactly the right time in the building process, when the level of completeness is just appropriate. Craftsmen dislike being stopped in progression, having to wait for someone with the right equipment to come when they have the capacity to do it themselves. As an illustration, one might note that the early-stage measurement on the building shown in **Figure 4** was performed a little bit too early; one balcony door was not mounted yet, the result of challenges in timing.

The importance of final-state measurement

Quite recently the airtightness of the whole building from which **Figure 1** is shown was measured. In this case governmental funding for passive house activity, requiring airtightness measuring, was released based on the preliminary measurements from the tents. It could have been awkward, though, if the required airtightness goals were not met in the final measurement of the whole building. Fortunately, the final-state measurements met the ambitious goals. Both builder and customer were happy.

Experience from several measurements in both early stage and in finished stage on the same building shows that one might end up with a poorer airtightness at the final stage compared with the early-stage-measurements. In fact, many things happening during the late part of the building process may cause extra air-leakages to the buildings. Examples include ventilation ducts being installed in a late phase, with little attention to making penetrations airtight, or balconies being mounted delayed in the building process, the improvised anchoring causing leaks.

Figure 4. Norwegian wooden building being in early-wind-tight-stage. Windbreak layers are of nonwoven HDPE fabric. Some parts of the wall have gypsum boards in addition, to reach fire resistance goals.

The conclusion is that early wind-tight-stage measuring should be followed up by a finished-state measurement. The early wind-tight-stage measurement should be recognized as a good insurance for the builder against blunders or incidents causing trouble with the customer in a later stage. It also serves as a powerful tool in the process of gathering experience to achieve the intended level of airtightness, especially with unfamiliar processes, details and materials, and thereby becoming everyday practice in a rapidly changing industry.

The level of measurement accuracy for the fans and other equipment used is not extremely important, when used in early stage measurements. The purpose of these initial depressurisations is not data with high accuracy. We must assume that the following final measurements are carried out with sufficiently precise equipment. It is equally important that competent users of the equipment, who understand and perform this according to international standards, do these measurements.

CHANGE OF NORWEGIAN REGULATIONS: 3rd party independent inspection of design and workmanship for airtightness level is becoming mandatory at the start of 2013 for most of the Norwegian new buildings. It is going to be exiting to follow how this turns out and develops.

Measuring is being recognised as being needed to prove this important quality: *Detailed design is necessary, but not sufficient to reach targeted level of airtightness needed for low-energy buildings*. 3E

Research into the effect of improving airtightness in a typical UK dwelling

The UK's Airtightness testing & Measurement Association (ATTMA) is a trade body that represents the UK's leading air-tightness testing and consultancy firms. Most of the work undertaken by these firms is for the builders of new housing and buildings, who are required to prove that they have achieved the required level of air-tightness in their buildings in order to satisfy Building Regulations.

ATTMA

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In England and Wales, it has been a requirement that all types of new buildings and dwellings have to be tested since 2006. Prior to this, most buildings were neither designed nor built with air-tightness in mind; primarily because there was no requirement for testing. Consequently it is generally accepted that older UK houses and buildings are on average quite 'leaky'. Indeed, research conducted by the Building Research Establishment (BRE) over 10 years ago determined that a typical UK dwelling leaked at a rate of 11.48 m^3, per m^2 of their external envelope, per hour at an air pressure differential (between inside and outside of the envelope) of 50 Pa (see below). The minimum standard permissible under current UK Building Regulations is $10m^3/(m^2.hr)$ @50 Pa, although usually in order to attain overall compliance with calculated CO_2 limits, a far lower (better) figure has to be both specified and achieved.

Effect of envelope airtightness on energy use?

A frequent point of discussion among ATTMA members is the fact that, set against this background of generally 'leaky' existing building and housing stock in the UK, there is an opportunity to significantly improve the energy and carbon performance of our existing building and housing stock by means of simple, low-tech but effecting air-sealing measures. The barrier to this seems to be in lack of awareness as to the extent of the benefits that can be realised by this approach. This is reflected in the range of attitudes that air-tightness specialists come up against amongst builders, building inspectors and even building managers/owners; ranging from some who regard air-tightness as being as fundamental and vital as weather-tightness to those who regard it with apathy, scepticism or even hostility.

Experiment needed for reliable data

What is needed is more reliable *evidence* as to the positive impact that improved air-tightness can deliver in a typical UK building or dwelling, alongside an appropriately designed and controlled ventilation system. Aside of those whose at the extremely sceptical end of the aforementioned spectrum, most building professionals, and indeed the general public would acknowledge the general principle that a less air-leaky building is likely to be more energy and carbon efficient, and more comfortable for the occupants (providing the ventilation is appropriate). However, the problem is the lack of a sense of scale or quantity.

With this in mind, in 2010 the ATTMA decided to attempt to provide some evidence by means of commissioning a research project by the BRE, who are themselves members of ATTMA and acknowledged experts in air-tightness, but who are also unrivalled in their ability to undertake building performance research projects of this type.

The brief given to BRE was to undertake research to demonstrate the impact on the space heating load in a typical UK dwelling that arises when the air-permeability of its external envelope is improved. For this purpose, the BRE provided two of its purpose-built 'test houses', located on the BRE's, Watford site. The two dwellings are largely identical mid-terrace houses situated side-by-side, with construction details that are typical of millions of existing UK dwellings.

The two dwellings in the test are largely identical mid-terrace houses situated side-by-side, with construction details that are typical of millions of existing UK dwellings.

The test methodology was that of whole-house co-heating testing, the principle of which is described below. In short, it is a method of accurately determining the aggregated thermal losses of an unoccupied building. The testing was undertaken by Mr Arron Perry and Mr Nigel Waldron from BRE's Building Technology Group overseen by Mr David Butler, between November 2010 and March 2011. Air-permeability testing was provided by Jamie Best of Melin Consultants.

Test buildings and testing procedure

The two similar houses were used in order to provide a 'control'. For each, the co-heating testing and analysis was conducted in two phases: firstly with them both having an equally high average air-permeability, then secondly with one having its air-permeability left high, while the other had its air-permeability made much lower by means of sealing up its fabric. Each "phase" of testing lasted several weeks in order to gather sufficient data for analysis.

Air permeability testing was used to determine the air-permeability of each house at the beginning and end of each testing phase.

Measured air permeability of test houses in the test phases 1 and 2.

	Phase 1 Air Permeability ($m^3/(m^2.hr)$ @50 Pa)	**Phase 2** Air Permeability ($m^3/(m^2.hr)$ @50 Pa)
House 1	15.60	15.60
House 2	15.78	4.88

The air-permeability levels for both houses were deliberately increased for the first phase of the testing in order to create a larger margin of measured improvement. This was done by the air-tightness tester deliberately introducing holes into the external walls and ceilings of the houses until repeated air-permeability testing showed that both houses were exhibiting an air-permeability of between 15 and 16 ($m^3/(m^2.hr)$ @50 Pa). They then both subjected to co-heating testing to demonstrate establish the baselines for each. A few weeks later, House 2 was sealed and tested down to just under 5 ($m^3/(m^2.hr)$ @50 Pa), while House 1 was left unchanged. The measurement of heat loss then resumed, with House 1 effectively acting as the 'control'.

The Co-heating Test Methodology

The co-heating test is a practical method of determining the combined fabric and infiltration heat loss of an unoccupied house. It involves electrically heating the houses to a constant indoor temperature. Correlation of the measured electrical heat input and solar heat gains with indoor and outdoor air temperature difference allows an estimation of the whole house heat loss coefficient.

Since the tests were undertaken during winter, the room air temperature in each house was controlled to a constant temperature between 18 and 23°C using electric heaters so that an average temperature difference of between 10 and 20°C was maintained between room and outside air temperature.

Electric convector heaters were installed in the main rooms and were controlled on a zone basis by accurate proportional temperature controllers with remote temperature sensors located centrally in the zone at approximately 1.5 m above the floor. The electricity consumed by the fans was accounted for by including them in the metered heater supplies. One pulse output kWh electricity meter (1 000 pulses per kWh) was provided in each zone. To maintain an even temperature distribution throughout the houses, all internal doors were fully open and air circulation fans were used to mix the internal air. The fans were installed on poles above each heater to prevent stratification and encourage air circulation without excessively high air speeds.

External air temperature was measured by a shielded sensor near the north elevation of the terrace. Solar irradiance was measured by a Kipp and Zonen pyranometer mounted on a weather mast on the north field area of the BRE site.

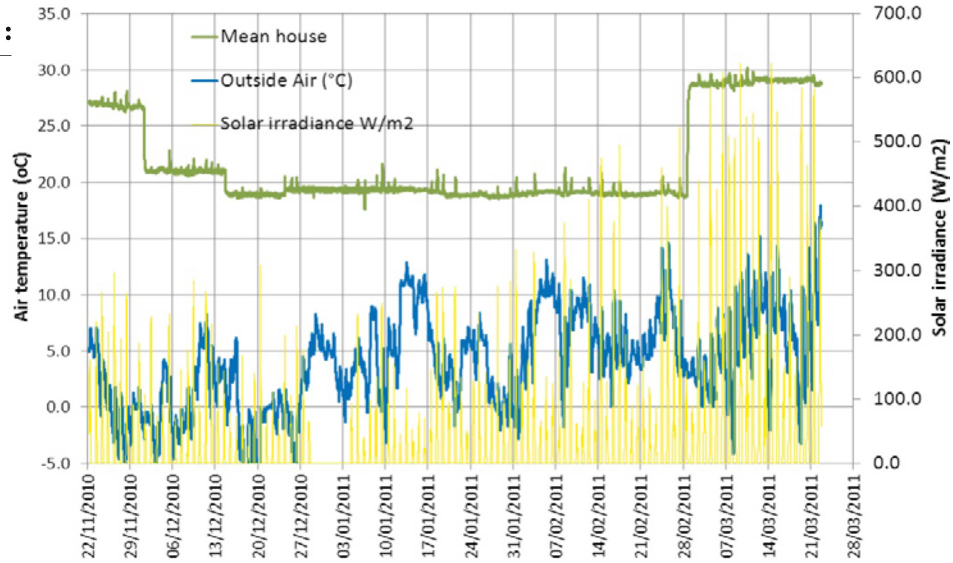
In order to minimise unaccounted for heat gains and losses all external windows and doors and other openings were closed and all electricity consuming appliances and lighting was switched off. Access to the houses was also restricted to an absolute minimum during the duration of the co-heating tests.

Electricity consumption, room air temperatures, external air temperature and solar irradiance were continuously measured and recorded using battery powered data loggers (Eltek SQ1000) with a recording interval of 15 minutes.

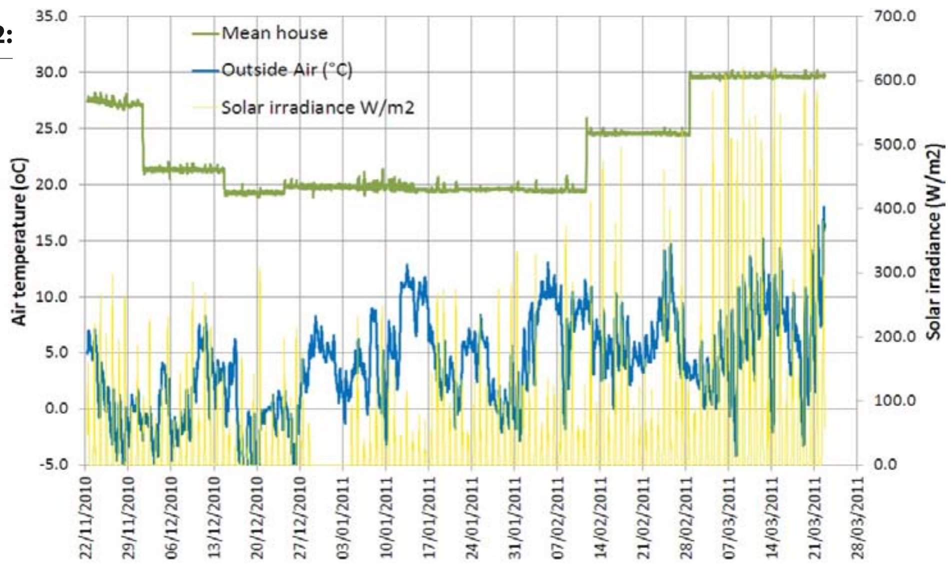
Solar heat gains were determined by analysing the measured solar irradiance data using a simple window solar heat gain model. The window model took account of the window glass area, orientation and glazing type. Raw solar irradiance measured at each house on a horizontal plane was apportioned to each vertical orientation using the fraction of hourly CIBSE cooling load data on each orientation (CIBSE Guide A, Table 5.19 Solar cooling loads).

The calculated solar gains were added to the measured electrical heating energy to determine the total heat input

House 1:



House 2:



Indoor and outdoor temperature, and solar irradiation. during the test for both houses.

necessary to maintain the specified mean internal air temperature. The houses were assumed to have low / medium thermal mass and therefore it was assumed that the majority of solar heat gains received during a day and absorbed into the house fabric would be released to the house interior in the same 24 hours period. Therefore the correlation of heat input with mean internal and external air temperature difference was assessed on a 24 hours or daily basis.

Test results

The room air temperature in each unit was controlled to a range of fixed temperature values using electric heaters so that an average temperature difference of at least 10°C was maintained between room and outside air temperature. Solar heat gains were determined by analysing the measured solar irradiance data using a simple window solar heat gain model.

Linear regression analysis yielded the following heat loss coefficients (with forced y-axis intercept of y=0):

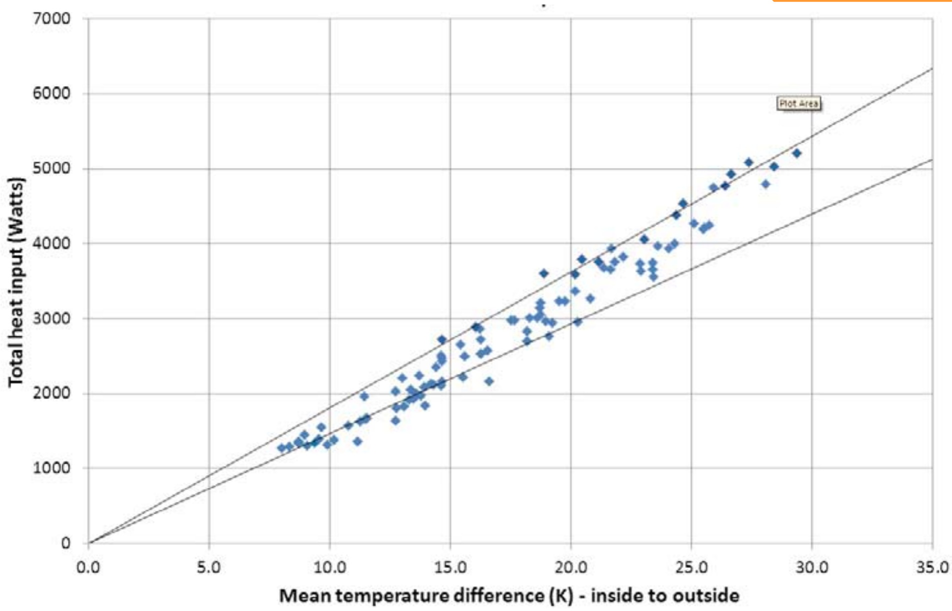
Heat loss coefficients calculated from the measures heating energy use during the test phases 1 and 2.

	Phase 1	Phase 2
	Heat Loss Coefficient (W/K)	Heat Loss Coefficient (W/K)
House 1	146.6 to 181.3	
House 2	151.5 to 179.4	105.0 to 116.3

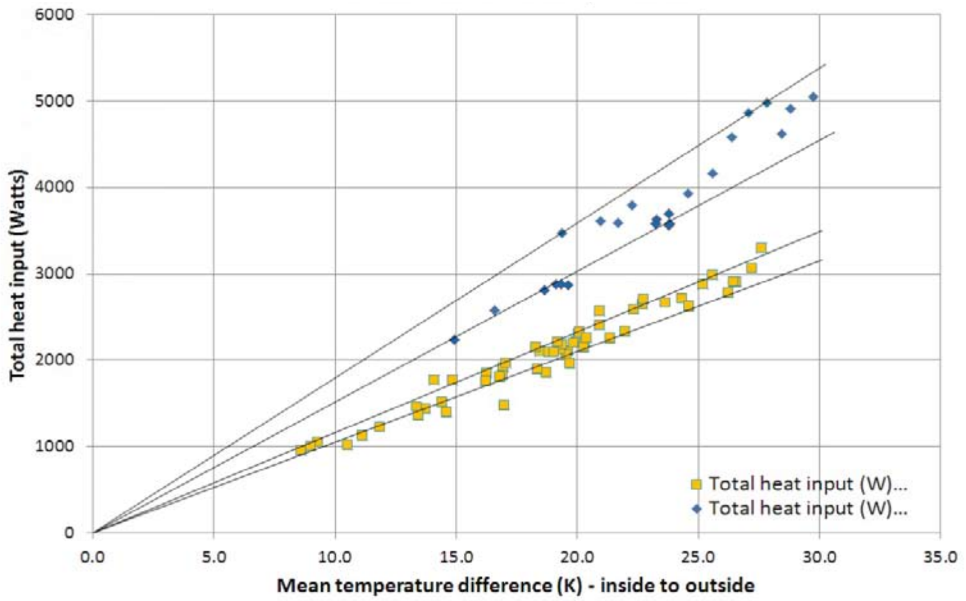
The difference between the lower and upper regression line coefficients for each data set is assumed to be the effect of wind speed.

Their relative heat loss performances can be attributed to almost entirely the difference in fabric air-permeability as all other factors remained the same for both;

House 1 – Total heat input versus dT:



House 2 – Total heat input versus dT:



Heat loss coefficient for both houses with different airtightness of building envelope. Upper lines correspond the permeability of 15.78 and lower lines 4.88 (m³/(m².hr) @50 Pa).

in particular, the climatic conditions that they were exposed to during the testing phases.

The overall conclusion was this: the reduction in heat loss in House 2 resulting from the air leakage sealing measures, corresponding to an improvement in air permeability from 15.78 to 4.88 (m³/(m².hr) @50 Pa), was between 46.5 and 63.1 W/K, equivalent to between 31 and 35% reduction in heat loss.

ATTMA argue that it is reasonable to assert that there exists a linear relationship between air-tightness and heat loss (assuming all other factors remain constant). Therefore, it would for example be reasonable to assert that an improvement in air-tightness from, say 11.5 to 5 m³/(m².hr) @50 Pa would yield a reduction in heat loss in the order of 15%. Therefore, if typical UK houses were remedially air-sealed from their current state (i.e. an average leakage rate of 11.5 m³/(m².hr) @50 Pa to a not unreasonable level of 5 m³/(m².hr) @50 Pa, then one could expect to see an average saving in heating costs of up to 15% over the life of the property.

Obviously this saving is at risk of being eroded by occupant behaviour and in particular by losses from ventilation. Nonetheless, weighed against the relatively minimal one-off cost of locating and permanently sealing the air-leakage sites, the argument is compelling.

Acknowledgment

Much of the technical content of this article is taken from the BRE's Report number 271-943, "Co-heating Tests on BRE Test Houses Before and After Remedial Air Sealing" By David Butler and Arron Perry. 3Ɛ

Swedish experience with airtight ductwork

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Why is it important to have a tight ductwork?

Many studies have identified defective ventilation systems and insufficient airflows as a main reason for occurrence of sick buildings - the supply air needed to assure a good air quality should thus reach the areas where it is needed and not disappear along its transport through the building.

Duct systems account for a large fraction of the energy use in a building. This is further increased with a leaky duct system. The supply air flow has to cover the sum of total nominal air flow and the leaking flow. With leaky ductwork this will lead to a considerable and costly increase of the needed fan power.

There are several good reasons to reduce the air leaks from ductwork:

- Correct air flows to and from the rooms are dimensioned to ensure that emissions and heat loads are kept within set values and that air quality (AQ) and thermal quality (TQ) are acceptable.
- Duct leaks can result in disturbing noise.
- When leaky supply and extract air ducts are installed above a false ceiling part of the air will take the simplest way, from the supply duct direct to the extract duct without bothering to pass through the connected rooms.

In spite of these good reasons to use tight ductwork we found in two EU projects that designers, installers, building managers and owners in some countries often ignore the benefits of airtight duct systems. This has probably resulted in poor ductwork installations in a large fraction of the building stock. In these countries, installation is probably often undertaken using conventional in situ sealing techniques (e.g. tape or mastic), and therefore the ductwork airtightness is very much dependent upon the workers' skills.

AMA – an old and reliable Swedish system to ensure high quality ductwork

Starting already 1950 – i.e. for more than 60 years back in time – we have been using a quite unique quality assurance system in Sweden covering all aspects of building and installation technologies. Practically all buildings and their installations in Sweden are performed according to the quality requirements in the AMA specification guidelines (General Material and Workmanship Specifications). These requirements are made valid when they are referred to in the contract between the owner and the contractor.

The requirements for tight ventilation ductwork systems were included in AMA already in the early sixties. Sweden has thus a long and unbroken tradition of demanding and controlling tightness of ventilation ductwork. During this long period, since 1966, the AMA tightness requirements have been raised in tact with technology improvements and increased energy costs.

AMA is a tool for the employer (developer/future proprietor) to specify his demands on the new building and its installations. It is a work of reference – you use the parts that are relevant for your project by referring to these parts in your building specification. As an employer – you have to state what you want, check that you get it, and be prepared to pay the price for it!

The requirements are based on accepted demands – the requirements are regularly updated in accordance with technology development and (LCC-) costs. The technology development has probably to some extent been influenced by the regularly increased AMA demands.

Changes of the demands are prepared by a working group and discussed with – and accepted by – building owners, contractors and consultants. The demands are to be specified in measurable units and in such a way that the tenderers and contractors understand them and are able to calculate a price.

Ductwork airtightness demands in AMA 1966 – 1972

It started with the AMA version 1966 when two "tightness norms", A and B, were defined. It was also requested by the contractor to spot-check the tightness in a minimum of 10 m² duct perimeter area.

In AMA 1972 the requirements were transformed into two "tightness classes" A and B (same as the EUROVENT classes today). Class A was the basic requirement for the complete duct system in the air handling system (i.e. including dampers, filters, humidifiers and heat exchangers). It was advised to raise the requirement to meet Class B when the system operates for more than 8 hours/day and the air is treated (cooling, humidification, high class filters etc.).

A ductwork system is not specified to be tight – instead the permissible leakage rate at a specified test pressure is stated as a tightness class – that is possible to measure!

Tightness classes in Eurovent (AMA)

A: lowest class; B: 3 times tighter than A; C: 9 times tighter than A, and D: 27 times tighter than A. The tightness classes are defined by a leak factor in l/s, m². The AMA has 400 Pa as standard test pressure. See lines in **Figure 1**.

In the USA (ASHRAE) the classes are raised in steps of two times tighter: C_L48: lowest class, C_L24: 2 times tighter than C_L48 and so on till C_L3: 16 times tighter than C_L48 (**Figure 1**).

With the Swedish AMA version 1983 Tightness Class C was added for round ductwork larger than 50 m² while Class B was required for round duct systems with a surface area smaller than 50 m² and also for rectangular ductwork. Class A, the lowest class, was only accepted for visible supply and exhaust ducts within the ventilated room. In AMA 1998 Tightness Class D was added (D is 3 times tighter than Class C). The use was not specified. It is an optional requirement for larger circular duct systems and where leakage can lead to hazards. AMA 2007 raised the requirements still another step – now also rectangular ductwork has to meet tightness Class C.

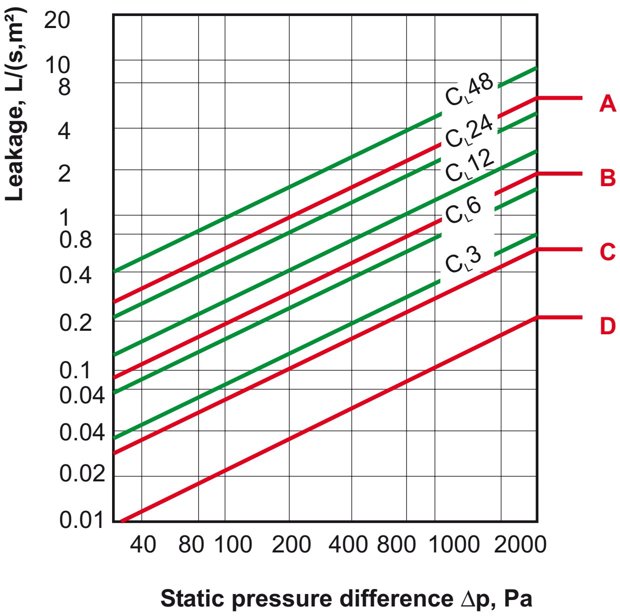

Figure 1. Comparison between European (Eurovent and AMA) Tightness Classes A – D and American (ASHRAE) Tightness classes C_L3, C_L6 etc.

How is the tightness tested – and by whom?

Requirements and demands can be worthless unless they are controlled. AMA thus also states the demands and the requirements for tightness testing of the ductwork. The leakage rate at a specified test pressure is stated – this is possible to measure! – and it is compared to the permissible value for the prescribed tightness class.

This control is normally done by the contractor as a spot check where the parts to be checked are chosen by the owner's consultant. This is specified in AMA and thus being a part of the contract (i.e. the cost for the test is normally included in the contract lump sum). AMA also states the first part of the ductwork to be tested to be 10% of the total duct area for round duct systems and 20% for rectangular ducts.

The control of whether the leak factor value is acceptable is measured by the contractor normally under the supervision of the owner's consultant. The contractor is required to hand over a filled in and signed AMA protocol to the owner.

The tightness of the ductwork is controlled in the following manner: The consultant points out which part of the ductwork he wants controlled.

The test fan ("provfläkt") is connected to the ductwork where all openings are sealed ("täcklock") (**Figure 2**). The fan is started and the airflow ("läckflöde") needed to keep test pressure ("provtryck") at e.g. 400 Pa is measured. The actual leak factor is calculated by dividing the airflow (l/s) by the in situ measured (or taken from drawings) surrounding area of the tested duct system. The result is then compared with the leak factor for the prescribed tightness class as found in the AMA tables.

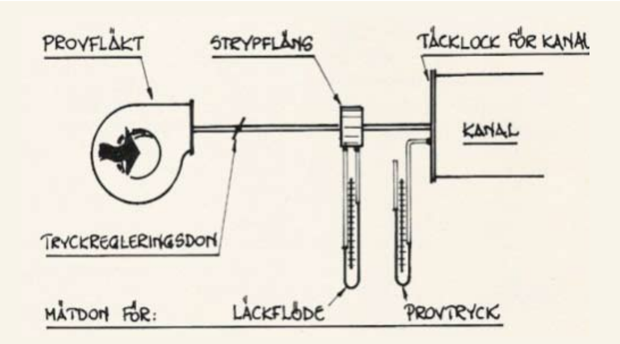

Figure 2. The test equipment for measuring the ductwork leakage from an article in 1966 by same author as this article – when AMA first required ductwork tightness. The principle is still the same!

If this result is equal or lower than required the system is accepted. If not the contractor has to tighten the leak points and measure this part anew. He is now also required to check a new system part of the same size. (This is specified in AMA to be a 10% part of the system for round duct systems and 20% for rectangular systems). If also this second measurement shows an unsatisfactory result he has to check the whole system until everything is accepted.

Is the testing worth the money?

The costs for the tests – the first 10%, then next 10% if not accepted and then the whole system - is part of the contract, i.e. covered by the contractor.

The mechanical contractor can either make the tightness test with his own personnel, provided he has equipment and skilled personnel, or he can use a specialized contractor. In both cases he has to cover the costs which can be quite considerable if the tests have to be repeated due to bad test results.

This has certainly led to high quality ductwork standard in Sweden for the following reasons.

The contractors do their best to avoid costly setbacks from inferior duct quality, the duct manufacturers are competing in inventing and marketing tight duct systems that are easy to install. Both circular and rectangular duct connections are provided with rubber gaskets that are very tight compared to older (and foreign) systems. New types of duct joints have reduced earlier laborious installation works.

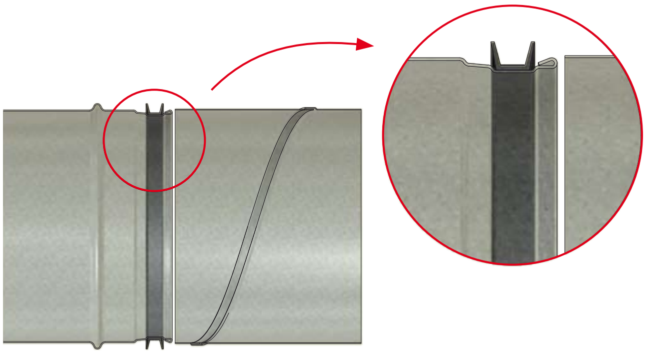

Figure 3. An example of a duct connection fulfilling Class C requirements. The rubber seal is compressed and tightens the gap.

Comparison of test results in three EU countries

The EU-project SAVE-DUCT found that duct systems in Belgium and in France were typically 3 times leakier than EUROVENT Class A, see **Figure 4**. Typical duct systems in Sweden fulfilled the requirements for EUROVENT Class B and C and were thus between 25 – 50 times tighter than those in Belgium and France.

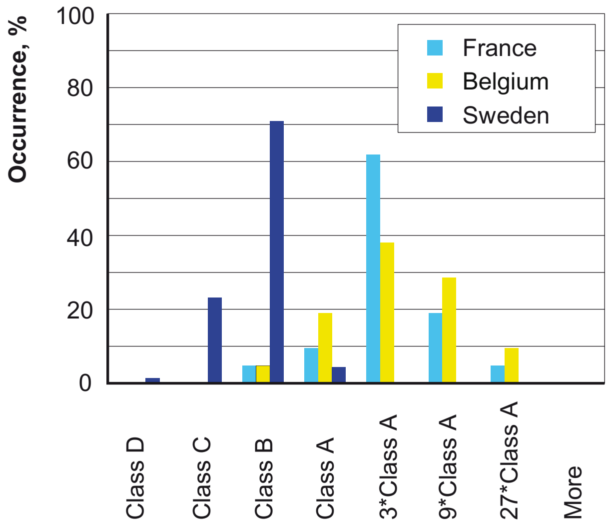

Figure 4. Results from the EU-project Airways. In the figure the bars show the percentage of tested ductworks in each tightness class. The tightness class 3 x Class A etc. had to be expanded to fit the results from leaky ductworks in the evaluation.

Figure 5. The supply air duct for the flat is fixed to a light framework at the ceiling. The duct is hidden behind a cladding fixed to the same framework – everything is done, quickly, by the duct fitter.

Why this large difference?

The most probable reason for this large difference is that Sweden has required tight ducts since the early sixties whereas in the two other countries tightness of ductwork is normally neither required nor tested.

Renovation of ventilation systems

During the period 1965 – 1975 it was decided by the Swedish Parliament that a large number of dwellings should be built to solve the acute crisis and reduce the housing queue and improve the dwelling standard. Statistics show that 1 006 000 dwellings (thus the name "The Million Program") were built during this period mostly in multi-family buildings but also to some extent in row houses. These houses have now reached an age when most of them are in acute need of renovation, not least when it comes to their installations. A standard ventilation principle in those buildings was extract ventilation with air being supplied from the outside through grilles in the external walls.

A common renovation solution today to improve the ventilation is to install a supply air system, keep – but clean and tightness test – the extract ducts and connect both duct systems to a new air-handling unit installed in the attic space. This provides several important improvements: the air intake is thus placed high up toward the back side of the building instead of at low level toward the street, the supply air (even though it is much cleaner than in the previous case) passes through a high class filter (Class F7 is a common standard), a heat exchanger reduces the energy use. The noise from the fans in the unit is attenuated to reduce the noise transmitted through the ducts to the flats.

To install a new supply air ductwork in an existing occupied building requires new installation methods. The inhabitants of the house should be disturbed as little as possible and for a very short time, preferably only during one day. This is of course a new and interesting market for the suppliers and several similar methods to solve this have been designed.

The illustrations show one of these systems where all the necessary components are prefabricated.

Another example when an old ventilation installation was replaced can be found in a high-rise office building in downtown area of Stockholm.

This building was the first of five rather identical high-rise office buildings in the City Centre of Stockholm (**Figure 6**). The architecture of the building was the result of an architectural competition (all five buildings, similar in height and dimensions, had its own architect). They were the result of a drastic reconstruction of a large part of the downtown area of the city when most of the old 18^{th} and 19^{th} century buildings were torn down and replaced with new office and commercial buildings.

The building was inaugurated in 1959, which was an extremely hot summer in Sweden. As typical for the time, the window/wall ratio was high, 76%. Following the normal design in Sweden at that period, the building was not equipped with any comfort cooling.

The supply and exhaust air was distributed through concrete shafts connected on each floor to branch duct systems. As there was no shadowing from other buildings the indoor temperature during the hot summer 1959 raised to above 35°C and the top floors of the building had to be abandoned for a few weeks.

After nearly thirty years of operation the building was thoroughly renovated in 1997. All installations were refurbished and the old ventilation system replaced with a modern air-conditioning system. New plant rooms were built on the roof of the building connecting to the old concrete shafts.

Instead of using the shafts as plenums for supply and exhaust air respectively, the shafts were literally filled with circular ducts as each floor plan was provided with its own separate supply and extract ducts. As each floor represents its own fire cell, the supply and exhaust ducts are provided with fire dampers (and regulating dampers) in the rooftop plant room as shown in **Figure 6**.

This technical solution required that fifteen ducts were installed in each of the shafts. This was possible by using circular ducts. The ducts were also delivered in 6-m lengths thus reducing the number of vertical joints considerably. The very compact installation reduced the necessary space for the vertical shafts and increased thus the floor area that could be let.

The design of the duct systems had to be studied in detail on how the supply and extract ducts were entering to or emerging from the shafts to prevent unnecessary collisions and facilitate the installation work. The ducts were tightness tested in turn as they were installed to prove that they were fulfilling the tightness requirements of Class C.

Conclusion

This Swedish way of working has been shown to be very effective in raising the quality of ductwork. Our long time focus on ductwork quality in Sweden has resulted in very low air leakage in normal Swedish duct installations which has promoted air quality, thermal comfort and sustainability.

Figure 6. Ducts for the different floors pass down through common shafts, one for supply and one for extract air. The photo shows part of the supply ducts with their fire dampers.

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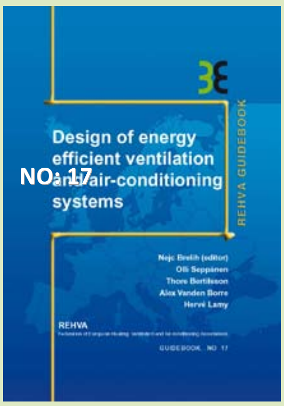

Ductwork airtightness requirements in Portugal

Portugal introduced, for the first time, in the 2006 Building Regulations, a requirement on the airtightness of the ductwork in new HVAC installations. A test is required during commissioning. Data on compliance is however still quite scarce to conclude how effective this requirement is in practice.

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EPBD context and CEN standards

The EU Directive 2002/91/EC and its recast published in 2010 (Directive 2010/31/EU) on the Energy performance of Buildings (EPBD) only include requirements for regular inspection of air-conditioning systems of an effective rated output of more than 12 kW (article 15), as well as heating systems including a boiler with nominal power above 20 kW (article 14). Inspections should identify opportunities for removing inefficiencies in the whole systems in a cost-effective way. There is no specific requirement for ductwork air-tightness, but this is certainly one issue that inspectors should analyse because leaking ducts have an important role in increasing energy consumption in air-based heating and cooling systems.

EN 15240 describes the methodology to perform inspections for air conditionning systems. However, given the large share of ventilation systems in the energy use in buildings, CEN also developed EN 15239 for the inspection of ventilation systems, even when they are not included in the strict scope of article 15 of the EPBD. Together with EN 15378, concerning the inspection of heating systems, these standards cover the inspection of HVAC installations.

Test procedures and measurement methods for air conditionning and ventilation installations are described in EN 12599. They include checks, for instance, of the accessibility and cleanliness of the system according to EN 12097 and EN 15780, as well as measurements, e.g., of airflow rates or ductwork leakage (with reference to EN 12237 and EN 1507).

Commissioning requirements in Portugal

As part of the transposition of the 2002 version of the EPBD, new regulations were adopted in Portugal and came into force in 2006. Requirements for new HVAC systems included for the first time a set of mandatory tests that must be carried out during commissioning, before the building receives its use permit.

Although there is no specific requirement on duct airtightness for new HVAC systems in both versions of the EPBD, its relevance can be argued on the basis of the following arguments:

- The overall goal of the EPBD is to obtain energy-efficient buildings. When a new building is completed, all its components, both fabric and technical systems, should be energy-efficient. Although the Directive 2002/91/EC only required MS to put in place minimum requirements for the building envelope, the recast EPBD corrected that oversight and it now foresees minimum requirements for both envelope and technical systems components. It thus seemed logical, even back in 2006, under the umbrella of the first EPBD, to impose a minimum performance requirement on ductwork airtightness as part of the overall energy-efficiency requirements in the Portuguese building regulations.
- If a new ductwork system is not airtight from the start, it will be a lot more difficult and costly to make it airtight later, after an inspection report identifies this opportunity for improvement. Recommenda-

tions for improvements must be cost-effective and it is often too costly to replace or to improve the performance of an inefficient ductwork system. Therefore, it also seemed logical that, in new buildings, ductwork had to be airtight when it was first installed.

Therefore, the 2006 Portuguese building regulations focussed on ductwork airtightness for new systems being installed, rather than just considering improving ductwork performance in the context of the regular inspections required by the EPBD.

The aim of the tests is to demonstrate that the installation is functioning as designed, in operational terms, but also meeting the minimum energy efficiency and indoor air quality (IAQ) targets set in the legislation.

Proof of the results of these tests, consisting of a detailed report, must be handed to the Qualified Expert (QE) who will issue the Energy Performance Certificate (EPC) for the building, who may ask for further tests if he/she is not satisfied with the report or just for confirmation (random check). Often, the QE is present while the commissioning tests take place. The EPC is required by the local authorities before issuing the building's use permit.

Tests on the ventilation system include:

- Airflow delivered to each room in accordance with design parameters;
- Overall cleanliness of the whole ductwork and other components, such as air handling units and fans;
- Airtightness of the ductwork.

The regulations do not require a specific testing methodology, but tests must follow recognised procedures, such as described in EN 12599.

Ductwork airtightness test

Ductwork air-tightness is often considered to be an issue in cold climates only. There has however been a significant amount of work in hot and mild climates, in particular in the US, that demonstrates the important energy savings potential that can be achieved by reducing duct leakage.

In Portugal, up until 2006, there was no check on the quality of the ductwork (most often, building owners did not require the check simply to avoid its cost), and its performance was in general quite poor (high leakage, cheap materials used), resulting in significant losses, with important negative consequences in terms of the energy efficiency of the whole installation (more air had to be circulated and treated to compensate for the leakage). Moreover, it was often impossible to meet the minimum fresh air rates in many spaces, resulting in degraded IAQ levels. The new regulation aims at ensuring minimum levels of IAQ and improved energy efficiency during operation of the building, by adopting a life-cycle perspective and moving away from the up-to-then prevailing strategy of lowest possible first cost.

To comply with the Portuguese regulation, ductwork leakage of air conditioning installations of buildings larger than 1000 m² may not exceed 1.5 l/s.m² under a static pressure of 400 Pa (Class A limit according to EN 12237 is 1.32 l/s.m² at 400 Pa). Air-tightness tests should be carried out using the following procedure (**Figure 1**):

- A 10% random sample of the ductwork is selected and tested by the inspector. If the measured leakage is below 1.5 l/s.m², no further testing is required;
- If the first test is not satisfactory, a second test is performed, after the contractor takes corrective measures, again on the initially tested ducts plus an additional randomly selected 20% of the ductwork. If these tests are satisfactory, no further testing is required.
- If the previous test is still unsuccessful, the contractor must take additional corrective measures and the final test(s) must cover the whole ductwork until the required airtightness is met.

This procedure was inspired by the AMA requirements in Sweden.

The new regulations in action

The new regulations apply to buildings larger than 1000 m² that begun their licensing procedure after 2006. Taking into account design and construction, this cycle usually takes, for large buildings, at least 3-4 years before completion. Therefore, there are not yet much data on the success of the new regulations. The first large buildings that had to comply with these new regulations only finished the construction phase late in 2009 and during 2010. New construction activity has also been quite low during the last few years due to the prevailing financial crisis and, therefore, the number of buildings affected by these new regulations is still rather small.

However, there is proof that the market adapted to the regulations. The share of pre-fabricated round ductwork with quality seals between ductwork components increased significantly (from <5% in 2006 to 30% in 2010). For rectangular ducts, the technology evolved to

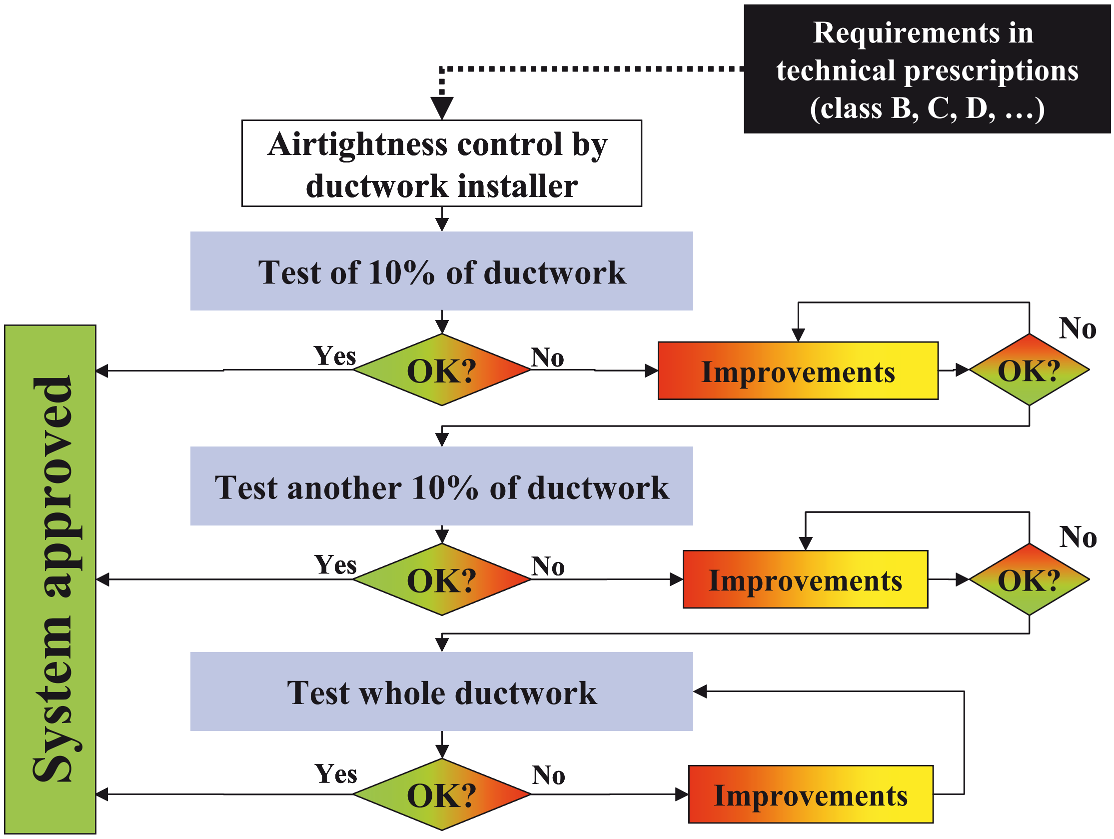

Figure 1. Swedish approach in framework of AMA procedures. The procedure now in use in Portugal is identical except for the initial requirement, which is defined in the regulation with a maximum leakage rate of 1.5 $l/s.m^2$ at 400 Pa (Class A limit according to EN 12237 is 1.32 $l/s.m^2$ at 400 Pa).

achieve better seals along duct sections and at unions between two consecutive sections, namely at the corners, representing now 20% of the market (extraction ducts carrying air that is not recirculated, e.g., from toilets and wet-zones, are still usually low-quality ducts). Welded and screwed joists disappeared since then. In parallel, a few specialized companies now offer duct leakage testing services in the market, while there were none in 2006.

Although only few EPCs have been issued for large new non-residential buildings so far, there is anecdotal evidence that the required commissioning tests (not just ductwork leakage) resulted, in most cases, in significant delays to the construction phase, with the corresponding negative backlash. Despite this, the new regulations that must be published to transpose the recast EPBD in Portugal, expected in 2013, are not expected to relax these air-tightness requirements for new ductwork to be installed.

Conclusion

It is too still early to say if the new regulations have been successful (the number of completed new HVAC installations falling under the new requirements is still rather small) and the data regarding the actual performance of few buildings constructed with the new requirements have not been fully analysed yet for lack of statistical significance. But ductwork technology evolved, and there is quantified proof that better quality components are now much more used, and ductwork leakage testing, as well as ductwork cleaning, are now new niche markets that appeared since the new regulations entered into force.

References

See the complete list of references of the article in the html-version at www.rehva.eu -> REHVA European HVAC Journal

Evaluation of air leakage and its influence on thermal demands of office buildings in Madrid

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Introduction

The major consequences of infiltration are the thermal losses derived from it, which account, in some instances, for high percentages of the total building's thermal demands [1] and therefore, in energy intensive buildings, cause important economic losses. However, air leakage careful analysis and management is usually the exception rather than the norm.

Four office buildings in Madrid have been analysed at two different levels: air leakage tests and mathematical modelling. In this way real *ELA*, and the instantaneous and mean infiltration values have been determined, as well as its effects on the heating and cooling demands. This process highlighted different recurring building pathologies, which, although only tested in this small simple, lead to belief this could be a clear picture of the current situation.

This analysis is a part of a bigger project on the multidisciplinary study of the energy behaviour of commercial buildings in Madrid, under the umbrella of the major commercial district development "Desarrollo Urbanístico de Chamartín (DUCH)".

Development

The methodology used is structured in two separate steps: firstly, the air leakage tests to determine the main parameters of the case study buildings. Secondly, modelling of infiltration allowing the characterisation of the transient model and the resulting data analysis.

Air leakage test

The different air leakage test standards consist in pressurizing and de-pressurizing the study zone using ventilators (usually placing a BlowerDoor [2]) and determining the necessary airflow to achieve a set pressure. In the present case the tests were carried out in the four buildings at store level.

This technique yields the Effective Leakage Area (*ELA*). Assuming the total building's air leakage through the different cracks can be represented as the infiltration through a mouthpiece of equivalent area, the cracks' dimensions can be represented as a single effective area [3], or *ELA*. Thus, the *ELA* is usually used, at a set reference pressure, to represent the leakage through the envelope.

However, as some previous studies have shown [4], and for a couple of the current analysed buildings, substantial infiltration occurs between the study zones and some adjacent ones, some of which are unconditioned, con-

Table 1. Characterisation of the analysed buildings.

Parameter	Units	Description	Building A	Building B	Building C
Year	year	Year of building	2010	2008	2009
N_plan	Storey	Number of storeys	6	10	4
Type	–	Type of construction	Heavy	Light	Light
Per_window	%	Percentage of window	> 90%	> 90%	> 90%
Surf_bui	m^2	Building's total envelope	5 398	10 632	7 448
Vol_bui	m^3	Building's total volume	25 147	93 600	36 689
Height_bui	m	Building height	23	42	15

Table 2. Summary results of the air leakage tests.

	Building A	Building B	Building C
ELA_{test} (cm^2)	7.479	5.483	1.295
ELA_{ZPD} (cm^2)	3.739	0	0
ELA (cm^2)	3.739	5.483	1.295
ELA (cm^2/m^2 facade)	6.36	17.69	4.56
Roof and slab infiltration ratio over the total (R)	0.23	0.02	0.04

sequence of a deficient building process. Thus, it becomes necessary to differentiate between external and internal air leakage. To achieve this, the Zone Pressure Diagnostic (ZPD) was used, which indicates what the corresponding *ELA* is for the analysis zone with regards to the adjacent and non-external surfaces, and so the *ELA* for the external ones [5].

Infiltration modelling

Infiltration can be broken down into a climate independent component (*ELA*), and another dependent on climate conditions, in a non-lineal effect. The climate independent component can be partially quantified by the field tests, whilst the climate interaction requires of a model to calculate its effect. The ASHRAE's [6] recommended Lawrence Berkeley Laboratory (LBL) have been used for this purpose. This model establishes that air infiltrations are a function of permeability of the building and the pressure differences through its envelope. These pressure differences are induced by air temperature differences (Stack effect) and the wind's pressure.

The above-described methodology has been implemented in TRNSYS, considering weather and monitored data, with the aim of achieving transitory infiltration values, and the determination of the effect of air leakage in the buildings' thermal behaviour.

Results and discussion

The exposed methodology has only been implemented in three of the four buildings originally selected. In the remaining one, although the air leakage test was tried, the required pressure differential values (50 Pa) were not achieved due to the construction pathologies. Both the influence of the pathologies in the building envelope and the ones in the internal partitions adjacent to unconditioned spaces posed too high an obstacle for the consecution of reliable results.

The characterisation of the three analysed buildings is determined through the parameters on **Table 1**.

Out of the field test undertaken for the three buildings, **Table 2** shows their characteristic values.

It can be observed that the infiltration levels between floors are only relevant in Building A, and that the ELA of building B is greater than for the other two buildings. These parameters are the ones used in the equations of the LBL methodology implemented.

The shown results, although being one of the objectives of the analysis, are not very intuitive. In order to make them clearer, they are applied to the different conditions and TRNSYS [7] models for the buildings, so that the air renovations due to infiltration and their effect on the buildings' thermal demands can be obtained. As an example, the infiltration instantaneous values for the same week in April are shown for the three buildings (**Figure 1**).

The results were synthesized into a weighted average value for infiltration (average infiltration values for the considered time interval, based on wind speed ratios for each orientation), a variation in demands and power on the Spanish regulatory reference (variation of thermal demands with calculated instantaneous infiltration vs. infiltration derived from the interpretation of the

Spanish regulation [4-8]), and variation in demands and power supposing no infiltration (variation of thermal demands with calculated instantaneous infiltration vs. no infiltration). **Table 3** shows values obtained using monitored climate data from February to September.

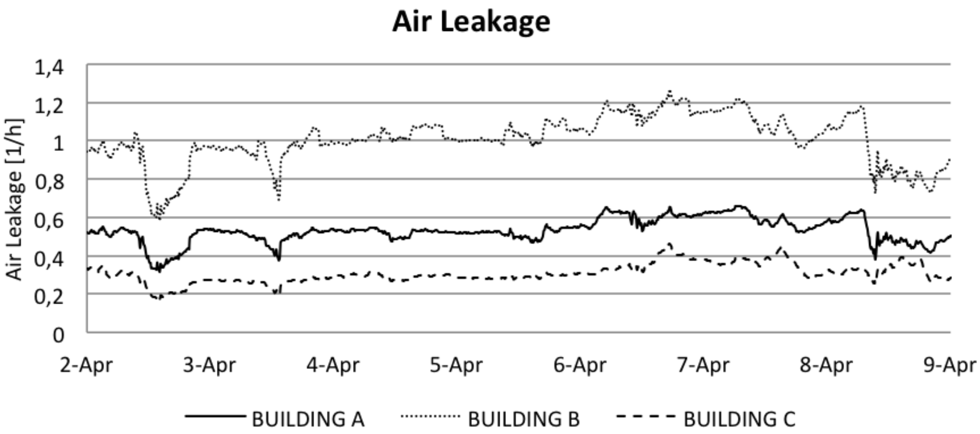

Figure 1. Instantaneous values of infiltration in the three buildings, for a week in April.

Where the variations on demands are obtained by comparing the excess (positive) or the default (negative) of the integrated temporal values of the reference case over the entire period, versus the integrated temporal values of the real case over the entire period. By following the same procedure, positive values for Power means that reference case have a bigger value, while negative one's means the opposite. The variables whose values are 100, indicate that in the reference case, the values of demand or power are zero.

In the data can be observed the proportion of the weighted infiltrations and, most importantly, the great variation in demands and powers between the models based on real data and those based on regulations. Also the weight of the infiltration on energy demands and powers can be noticed through the comparisons with no infiltration scenarios. The major influence on heating demands vs. cooling ones could be due to a combination of the high internal loads of these buildings, and because of minor infiltrations in summer season when, at the same time, non-occupancy periods exists.

It is worth mentioning, based on the established values and the singularities observed during the field tests, that, mainly in the A and B buildings, the result is a reflection of a poor quality in the construction process, rather than not meeting the current regulatory standards. Equally, comparing the results obtained with other references for office buildings in the US [1] or Australia [9], the magnitude order is very similar.

Table 3. Summary of transitory results of the infiltration models.

Parameter	Units	Description	Building A	Building B	Building C
$\dot{Q}_f\_ave$	1/h	Weighted average infiltration value	0,44	0,81	0,27
ΔQC_{SPAREG}	%	Cooling demand variation percentage on Spanish regulation reference	1	14	1
ΔQH_{SPAREG}	%	Heating demand variation percentage on Spanish regulation reference	–79	–100	–78
PC_{SPAREG}	%	Cooling power variation percentage on Spanish regulation reference	–4	–11	–4
PH_{SPAREG}	%	Heating power variation percentage on Spanish regulation reference	–72	–100	–83
$\Delta QC_{NOINFIL}$	%	Cooling demand variation percentage on no infiltration	3	17	3
$\Delta QH_{NOINFIL}$	%	Heating demand variation percentage on no infiltration	–94	–100	–91
$PC_{NOINFIL}$	%	Cooling power variation percentage on no infiltration	–6	–13	–6
$PH_{NOINFIL}$	%	Heating power variation percentage on no infiltration	–100	–100	–100

However, it is very complicate to compare the results for the three different buildings, as those have very different characteristic parameters. That is why the results were normalised based on the buildings' height (parameter affecting the wind speed directly), the *ELA* (air tightness level for the façade), and the form factor for the building (ratio envelope surface/volume). Normalizing each of these parameters for Building A the following are obtained:

Figure 2 is a graphic representation, hourly based and for a week in April, of the values in **Table 4**.

It is seen that the *ELA* is the main factor in the models. The second one is the height which conditions the wind on the façades. The form factor appears as a second order derivative influenced for the other two parameters.

Conclusions

The main conclusions refer to the feasibility, necessity and interest in undertaking this type of test, both in new construction and in existing buildings. It is also necessary to integrate detailed models in the design tools, verification and buildings' intelligent energy management, as well as in certification tools. Implementing such analysis in the building process would detect building pathologies, enabling the improvement of the construction processes by establishing priorities depending on the constructive solutions adopted. It would also allow the design process

Table 4. Infiltrations for the comparative analysis between buildings and on key parameters.

Infiltrations		Building A	Building B	Building C
Base Results	1/h	0.44	0.81	0.27
Normalization by height	1/h	0.44	0.62	0.32
Normalization by form factor	1/h	0.44	1.18	0.34
Normalization by ELA	1/h	0.44	0.56	0.77

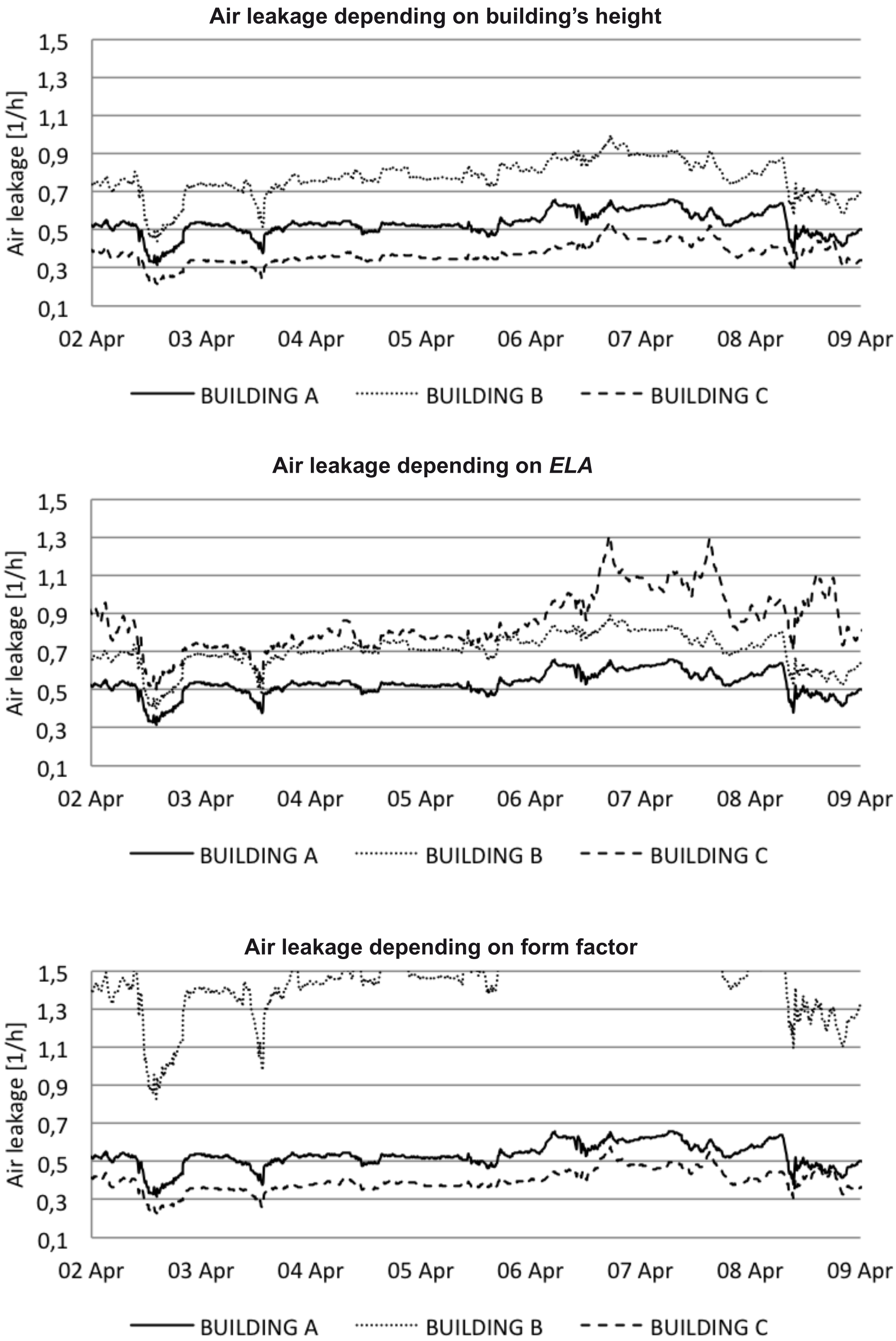

Figure 2. Infiltrations, for a week in April, of the three buildings considering B and C normalised to A-building's height (top), ELA (centre), and form factor (bottom).

Zone sealing for airtigthness testing (two first ones) and bottom one BlowerDoor installation for tightness testing

to be informed under cost-efficiency parameters, closer to reality certifications, as well as a more accurate intelligent building management. Equally, and taking into account other similar projects undertaken in different latitudes [10], a more deep analysis and from a stronger architectural point of view could relate constructive pathologies and architectural solutions, with different values for the present latitudes.

For the analysed buildings, their infiltration values are considerably high, with the consequent effect on the thermal demands and high-energy bills. This is mainly due to a poor construction process and practice, although having small form factors, or being low buildings, helps minimizing such effect. Equally, the order of magnitude in the variation of demands with respect to the normative case would justify, in terms of running costs, undertaking the necessary reforms to fix these problems. The strongest evidence lies in the building where the test could not be successfully completed due to the elevated air leakage both with the outside and the adjacent spaces. One should question if this is just an exception or the norm in old enough buildings (1992) in this geographical location.

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Energy efficiency strategy at the portfolio of a property owner

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Property owners are moving from implementing energy efficiency on pilot projects to improving energy efficiency on their whole portfolio. Such was the conclusion on the Third Sustainable Investment Conference held in Expo Real 2012 where different investors and investment managers introduced their strategy. French public investor Caisse des Dépôts et Consignations (CDC) was one of them.

At the end of 2009, CDC initiated the GRECO project with its asset manager AEW Europe, to anticipate the French environmental law "Grenelle 2". In accordance with the EPBD directive, the Grenelle 2 stipulates a regulatory obligation to reduce by 38% the energy consumption of existing commercial property stock by 2020. Although this law had not been formally enacted by an implementing decree, CDC was willing to promptly address the issue so as to limit the depreciation risk for its existing portfolio since refurbishment works would likely need to be undertaken, and to spread the refurbishment cost over time. In order to benefit from a broader view, this project was applied to both residential and commercial properties. A dynamic tool was built to store financial, environmental and technical data, help investment decision-making and monitor the implementation of the action plans.

Methodology

The project was first applied to assets in direct management and ownership. This portfolio represents one fourth of the total CDC's exposure to real estate. It consists in approximately 250 000 m², two thirds of which correspond to residential properties.

The impacts of future regulatory requirements on this existing portfolio were assessed through the analysis of the refurbishment work required to comply with the 38% objective either globally or asset by asset. First, energy audits were carried out on the whole portfolio. Actual consumption invoices (tenants and owner) were compared to thermal calculations so as to determine a breakdown of energy consumption per use (heating, cooling, lighting, ventilation, DHW, lighting, others). Recommendations were then issued to improve energy efficiency for each energy use. The resulting actions were stored in the platform, so that they could be combined into different scenario by the asset manager. The resulting refurbishment scenarios were assessed both according to energy efficiency and to cost effectiveness, as presented in **Figure 1**.

A dynamic internet platform was thus developed to:

- Store the collected data: The platform provides a space to store simultaneously financial, technical and environmental data.
- Help investment decision-making: The platform allows the asset manager to analyse the financial and environmental impacts of different refurbishment scenarios. The possible energy efficiency measures recommended by the thermal engineers on each asset are stored in a database. The asset manager can combine these actions to build refurbishment scenarios and assess their impact on the overall portfolio performance. He can also monitor the impact of buy and sale decisions.
- Monitor the implementation of the action plan: the tool is designed to monitor both the estimated consumption from the energy audits and the actual consumption.

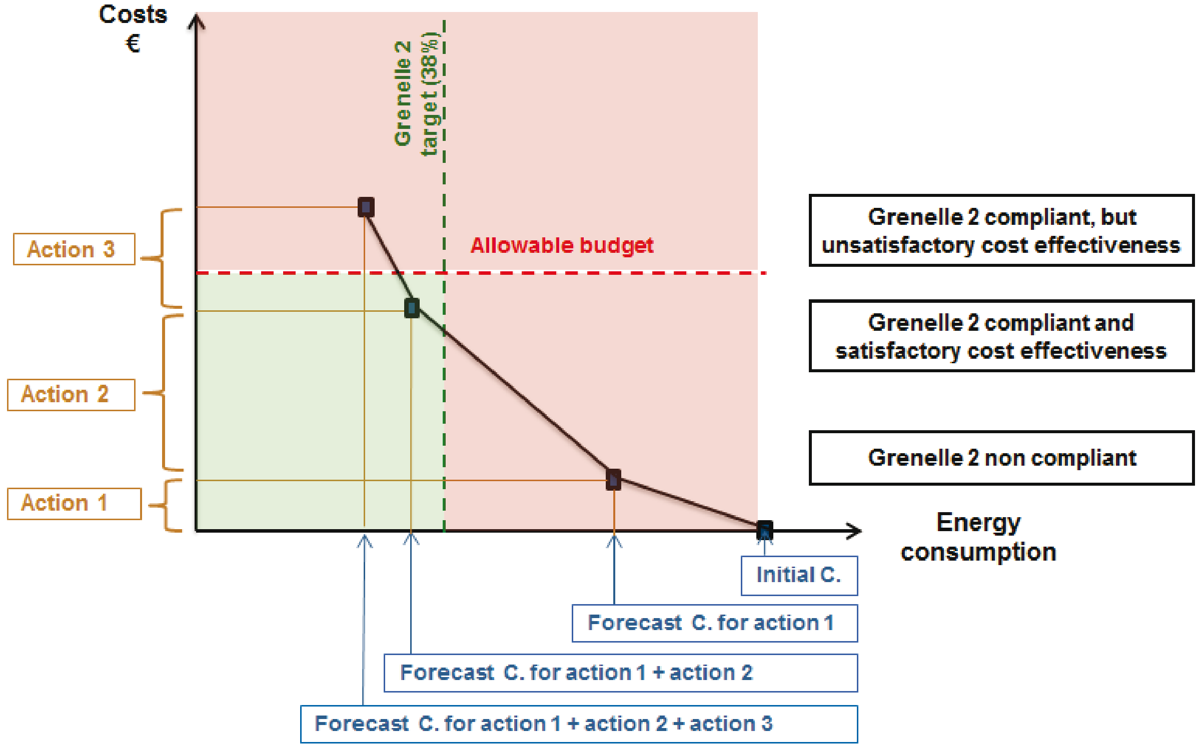

Figure 1. Underlying principles of the GRECO Project (Greco project).

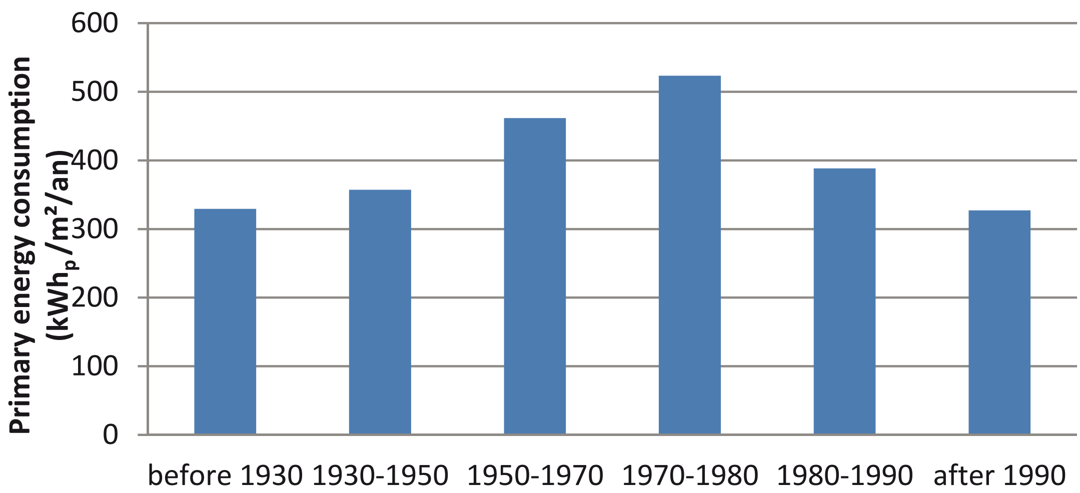

Figure 2. Average primary energy consumption per construction period.

The platform is designed to gather information on the different assets along the buildings 'hold period. This includes building plans, maintenance and operation expenses, energy and water consumptions from tenants' invoices… For new acquisitions, the platform should be able to store information from due diligence. Ultimately, this should provide the asset manager with an extensive "building passport" for all assets, with technical, financial and environmental indicators.

Results from the energy audits

The energy audits aimed to assess intrinsic building consumption. They included all energy consumption for heating, air conditioning and ventilation. Only plug loads for common areas were accounted for. Common hypothesis were used for occupancy, air change rate and temperature set-points. The results pointed out a relative homogeneity between buildings from the same period of construction (**Figure 2**). As shown in previous studies [**1**], the assets

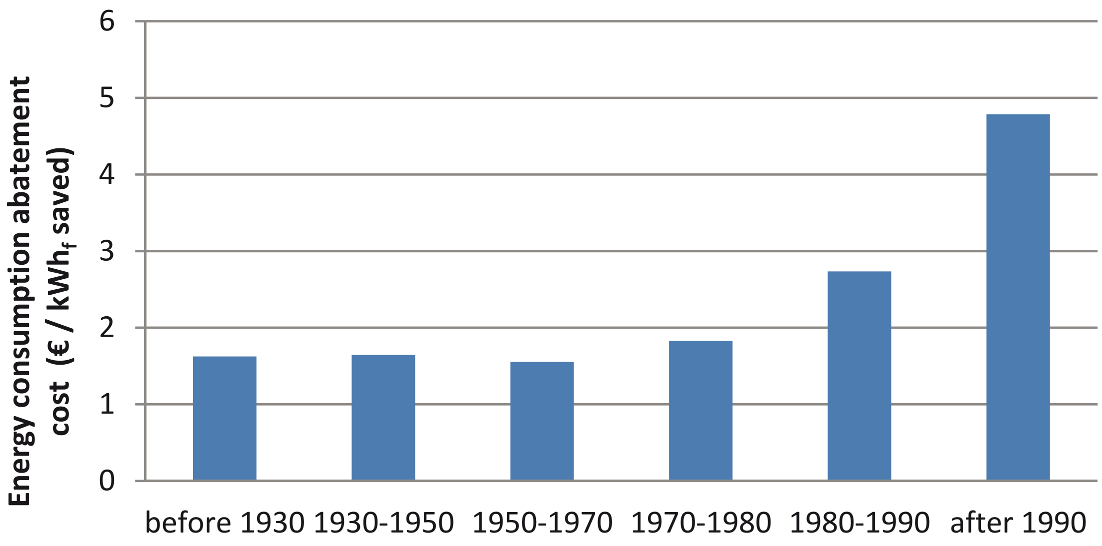

Figure 3. Average final energy consumption abatement cost per construction period.

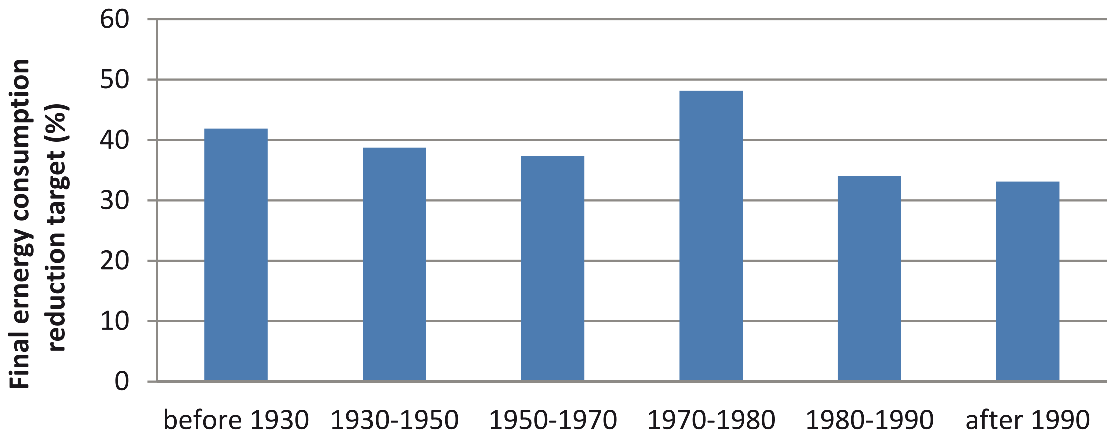

Figure 4. Final energy consumption reduction target per construction period.

built during the seventies have the highest energy consumption. Yet, this structure differs when analysing the cost of the energy saved thanks to the refurbishment work (cost efficiency of the refurbishment) (**Figure 3**) and the energy consumption reduction target that can be achieved at a reasonable cost (**Figure 4**).

Although they present the highest energy consumption, the properties from the seventies are among the easiest to refurbish. For this building group, it appears possible to reduce energy consumption by 48% for a cost efficiency of approximately 1.8€ per kWh$_f$ saved [**2**]. Conversely, the more recent buildings require important investment to reach only low energy consumption abatement.

These results are consistent with life cycle considerations and building obsolescence [**3**]. On average, heavy refurbishment works and equipment replacements occur after a timeframe of twenty to thirty years. Buildings from the last construction period will not be due for those refurbishment works until after 2020. It would not be cost efficient to refurbish them sooner, other than through regulation and lighting optimisation, which would not concern the building structure or the HVAC system.

Since residential properties do not yet present a legal obligation to refurbish, it was chosen to set a reduction target by 2030 for recent residential buildings rather than by 2020. Nearly all the refurbishment works recommended are feasible in occupied sites.

Table 1. Greco Project - Main indicators.

Portfolio	Time frame	Refurbishment costs (€/m²)	Cost efficiency (€/kWh$_f$)	Refurbishment cost to asset value (%)	Primary energy reduction target (%)
Commercial	2020	173	1.34	4.0%	39%
Residential 1	2020	100	1.07	2.1%	36%
Residential 2	2030	288	3.06	4.1%	32%

Ratios for decision-making

The first stage of this project has highlighted several indicators that were examined simultaneously for refurbishment decision-making. Main figures are presented in **Table 1**.

Refurbishment cost

The total refurbishment cost linked to energy efficiency upgrades appeared as mostly covered by the traditional budgets for major repairs and maintenance. This corresponds to the fact that major upgrades were timed to coincide with the replacement of components at the end of their life. The additional cost is difficult to assess and results mainly from the choice for more efficient installations. At a building level, the refurbishment cost and resulting payback periods were not the only criterion used for decision-making since they do not inform on cost efficiency or impacts on assets value.

Cost efficiency

Comparing the refurbishment cost and the energy consumption abatement target informs on the cost efficiency of the refurbishment scenario. It appears as the most suitable indicator to decide between different actions to meet the reduction target. The energy audits (**Figure 4**) highlighted discrepancies between assets with cost efficiency ranging from less than 1 to more than 8 euros per kWh$_f$ for reduction targets between 30 to 40%.

Refurbishment cost to asset value ratio

When accounting only for energy expenses, the investment payback period exceeds 8 years. Yet savings in energy expenses are not the only benefit from energy upgrades. The impact on the asset value should also be considered. The comparison between refurbishment cost and asset value was used to indirectly assess the risks linked to the regulatory obsolescence generated by "Grenelle 2". This ratio will depend on the functional quality of the asset and its location. Even with long payback periods, it may be more beneficial to refurbish if the asset market is likely to be concerned with a demand for greener buildings.

Impact on value - a case study

The impact of environmental upgrades on value was illustrated through a heavy refurbishment project which was undertaken at the beginning of 2010. This project was used as a case study to explore the links between energy upgrades and their impacts on asset value. Since the building is now completely commercialised, it was possible to compare predictions with effective data.

Background issues

Savings on energy expenses only cover a small part of the investment required by the refurbishment. Does this mean that energy upgrades are not worth it for the investors? Different studies have shown that the benefits offered by sustainable buildings amount to more than energy and water savings. In office buildings, sustainable features improve occupants 'comfort therefore boosting the employees' productivity. Academic studies have proven that these benefits are already reflected in the market with approximately a 10% premium in market values, a 6% premium in rental values and an increased liquidity in transactions (**Table 2**). Although one can wonder whether this premium will last or whether it will evolve into a discount for buildings with poor environmental performance, environmental features can no longer be ignored in refurbishment decision-making.

Data

Franklin building is an office building of 7500 m², built in the 1930´s and located in Paris Central Business District. In the beginning of 2010, as two of the main leases came to an end resulting in a two-thirds vacant building, a heavy refurbishment was decided. The project aims the HQE certification and the BBC [**4**] refurbishment energy label. It should be delivered by the end of 2012. The building is already completely commercialised with above average rental prices.

Table 2. Main results from academic studies on "green value" for office buildings.

References	Certifications	Market value	Rental value	Occupation rate
Fuerst and McAllister (2008)	LEED, Energy Star (USA)	31-35%	6%	
Wiley et al. (2008)	LEED (USA)		15-17%	16%-18%
	Energy Star (USA)		7%-9%	10%-11%
Miller et al. (2008)	LEED (USA)	10%		
	Energy Star (USA)	6%		
Kok (2008)	LEED, Energy Star (USA)	16%	6%	
Pivo and Fisher (2009)	Energy Star (USA) zones under redevelopment	6.7%-10.6%	4.8%-5.2%	0.2-1.3%
Fuerst and McAllister (2010)	LEED (USA)			8%
	Energy Star (USA)			3%
Eichholtz al. (2010)	LEED (USA)	11%	6%	
	Energy Star (USA)	13%	7%	
Chegut et al.(2011)	BREEAM (Londres, GB)	26%	21%	
Kok, Newell and MacFarlane (2011)	NABERS 5 stars (Australia)	9%	3%	
	Green Star (Australia)	12%	5%	
Fuerst and McAllister (2011)	Energy Star, LEED (USA)	25%-26%	4%-5%	

In order to assess the added value from the environmental retrofit, different scenarios were considered:

- Business As Usual (BAU): No refurbishment is implemented. Only standards maintenance operations are performed. The rental prices used correspond to rental prices for second hand buildings. The asset liquidity is deemed as poor thus leading to higher exit yield and higher vacancy.
- Conventional Refurbishment (RT): As regards energy efficiency, the refurbishment does not go beyond the current regulatory requirements. The asset is valued as first-hand building but does not benefit from a green premium (average rental price in the first-hand market). The asset liquidity is deemed to decrease over time.
- Green Refurbishment (HQE): This is the actual situation. The energy upgrade enables the owner to benefit from a green premium in rental prices and very good liquidity in the market.

The valuation was performed using a discounted cash flow method. To assess for the difference in values due to the absence of environmental features, longer vacancy periods in between leases were used in addition to the differences in rental and exit values mentioned previously.

Results

The main results are presented in **Table 3**.

Table 3. Main results from the Franklin case study.

	BAU	RT	HQE
Investment (€)	0	13 000 000	18 300 000
Annual rental revenue (full occupancy) (€)	4 288 611	5 685 730	6 054 200
Annual Rental growth rate (%)	1.50%	1.60%	1.70%
Discount rate (%)	7.75%	6.80%	6.70%
Vacancy period between leases (months)	12	10	9
Maintenance and operation costs (including vacancy) (€)	124 257	91 855	76 310
DCF t=0 calculation (accounting for investment costs) (€)	52 748 917	82 191 774	88 243 576
Asset value t=1(€)	52 748 917	89 926 650	100 377 224

For Franklin building, the discounted cash flow calculation (**Figure 5**) shows that the two refurbishment scenarios (RT and HQE) lead to lower cash flows respectively until years 7 and 9. Yet, over the long run, they present the highest NPV.

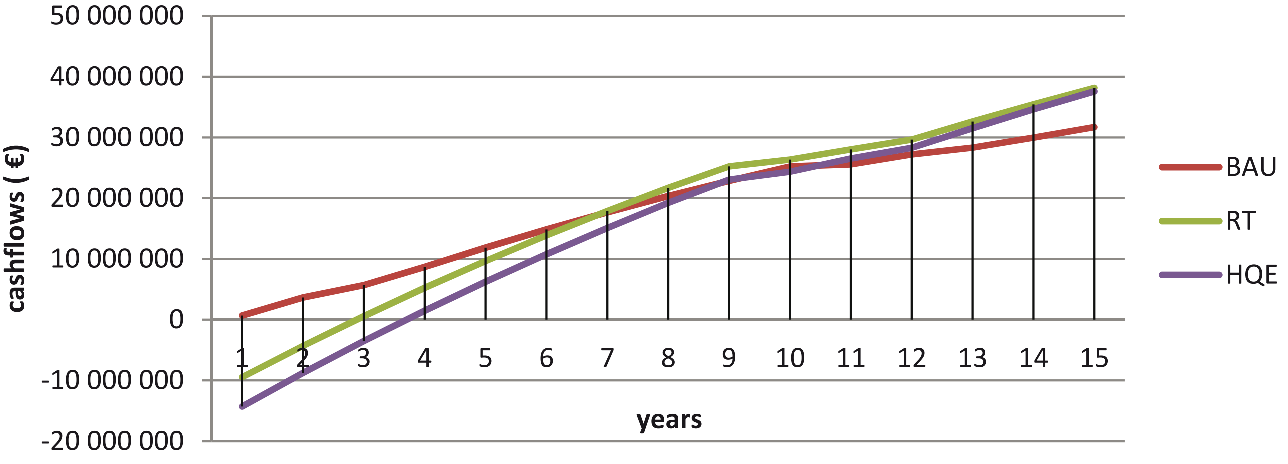

Figure 5. Evolution of the cumulated discounted cash flows over time.

However, as regards value, a refurbishment appears financially beneficial from the start since it enables the owner to increase its rental revenue and decrease future depreciation risks. The initial investment costs are offsets by the future benefits, in particular due to the higher exit rate that can be expected. HQE refurbishment which investment costs represent approximately a third of the initial building value enabled the investor to nearly double the initial value of its asset. In addition, it leads to a 10% value premium compared to RT refurbishment. These results highlight that traditional payback calculations accounting only for energy savings are misleading. They do not account for the main benefit of green refurbishment which appears in the long run.

Conclusion

As energy retrofits become a regulatory requirement, investors will require energy efficiency strategy at a portfolio scale. Decisions will not only concern choosing refurbishment scenarios within buildings according to technical criteria, but will also require prioritising between assets to maximise the value of the portfolio over time according to financial and environmental criteria.

Greco project was designed to meet these stakes. The first phase of this project has already been implemented with the design of a platform to store assets characteristics and possible refurbishment works. The data collection was a crucial step for this phase since data were scattered among the different actors. The main conclusion from the refurbishment recommendations highlighted that energy upgrades will not require an additional budget but will mainly be supported through a reallocation of the existing major repairs and maintenance budget.

The main benefit from green refurbishment lies in its impact on long term value. Whether on a pessimistic (depreciation of poor performing building) or on an optimistic scenario (premiums for the environmental-friendly building), green retrofit should not be only analysed through conventional paybacks period but considerations on their impact on the possible evolutions of assets value should be accounted for. Value distributions instead of a single expected value can also be used to inform on risks and uncertainties.

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[3] In its 2012 report on the impact of "Grenelle 2" on building obsolescence, the research center on commercial real estate in Paris region, ORIE, assessed the investment required to achieve Grenelle 2 targets by considering building refurbishment cycles. It showed that the target was reasonably achievable if refurbishment work were implemented according to the building maintenance cycle and if energy consumption was optimised through regulation.

[4] BBC label corresponds to an intrinsic primary consumption of 80kWh/m^2.year.

A new innovative Ground Heat Exchanger for heating, cooling and energy storage

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Uponor has developed a new innovate ground heat exchanger in conjunction with the MESSIB project co-financed by the European Commission under the Seventh Framework Programme (FP7).

The overall objective of MESSIB project is the development, evaluation and demonstration of an affordable multi-source energy storage system (MESS) integrated in building, based on new materials, technologies and control systems, for significant reduction of its energy consumption and active management of the building energy demand.

Among the innovative elements in MESSIB is Advance ground storage (GS) technology combined with radiant systems and ground thermal contact improvement by the development of a conductive fluid material (CFM). The basic idea behind energy storage in buildings is to provide a buffer to balance fluctuations in supply and demand.

The need for energy storage

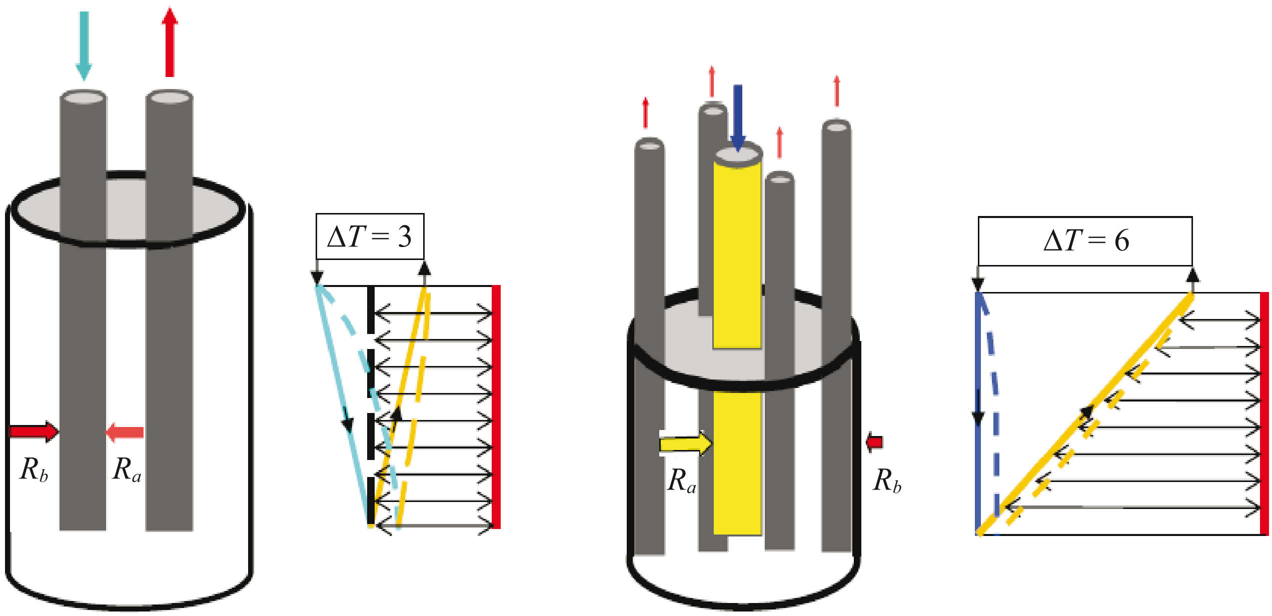
One of the challenges of today's energy systems is to way to match the demand and the supply. Reliable storage systems for short as well as long term are hence essential for efficient energy systems and further integration of renewable sources.

State of the art storage technologies for thermal energy include: Underground thermal energy storage (UTES), water tanks above ground, rock filled storage with air circulation, phase change materials (PCM) and thermo-chemical storage. The scope of the MESSIB development on thermal storage is to increase of the energy efficiency and indoor comfort in buildings by the reduction of the energy demand and the decrease of thermal gradients and temperature variations.

The Uponor development TIL-GHEX

The Uponor development under MESSIB is a so-called TIL-GHEX (Thermal Insulated Leg – Ground Heat Exchanger). It consists of a central thermally insulated pipe (40 mm) and a number of (between 6 and 12) outer active pipes (16 mm) acting as heat exchangers connected through a manifold at the bottom and at the top of the borehole.

The high number and small diameter of the outer pipes will increase the efficiency of the heat exchange and hence increase the thermal performance simply because the surface area between the collector and the surrounding ground is higher. Using a laminar flow the pressure drop in the outer small dimensioned pipes is minimized and there is no increased pressure drop over the circulation pump compared to the larger pipe dimension in traditional collectors. Since the Uponor TIL-GHEX ground energy collector is able to maintain a low borehole thermal resistance even at low flow rates, one can also take advantage of utilizing variable speed pumps and hence save energy without a negative influence on the heat transfer coefficient. The idea behind the thermally insulated central pipe is also to be able to keep a high temperature drop over the heat exchanger which is beneficial for cooling purposes.



Design principle of the TIL-GHEX compared with a traditional U-collector design.

Comparison with traditional U-pipe storage and collectors

The efficiency of a ground energy borehole is influenced by two factors. Firstly, the temperature difference between the inlet and the outlet flow of the collector. Secondly, the heat transfer coefficient between the collector and the surrounding ground which is normally referred to as the inverted value of the thermal heat resistance. The second factor is also influenced by the total surface area between the collector and the surrounding ground. Two main parameters influence the thermal heat resistance: The thermal resistance between the upward and the downward going flow (R_a) and the borehole thermal resistance (R_b).

One of the drawbacks with conventional collectors is that there is an undesired heat transfer between the upward and downward going flow. The thermal resistance between the upward and downward going flow is mostly denoted Ra and should be as high as possible. With Uponor TIL-GHEX ground energy collectors that undesired heat transfer is minimized through the insulated central pipe causing a higher R_a. The other drawback with conventional collectors is that the desired heat transfer to and from the surrounding ground is low compared to what can be obtained from a physical point of view. To obtain a high heat transfer between the fluid in the pipes and to the surrounding ground, the borehole thermal resistance denoted R_b has to be low.

TIL-GHEX benefits

The TIL-GHEX allows a higher energy transfer between the ground and the collector to a low borehole thermal resistance. This means that the depth of the borehole by up to 50% with the same thermal output. While the TIL-GHEX collector is more costly than a conventional collector, the total costs of installation are lower due to the reduced borehole depth.

The TIL-GHEX collector displays a high thermal resistance between the downward and upward going flow regardless of the flow rate. In contrast, the performance of conventional collectors depends on the flow velocity, with high losses at a low flow rate and clearly inferior performance even at high flow rates.

In summary the Uponor TIL-GHEX collector extracts a maximum of thermal energy which is transported up to the ground surface by a number of low diameter outer pipes (between 6 and 12). This applies to the heating mode. For cooling the direction of transportation is the opposite.

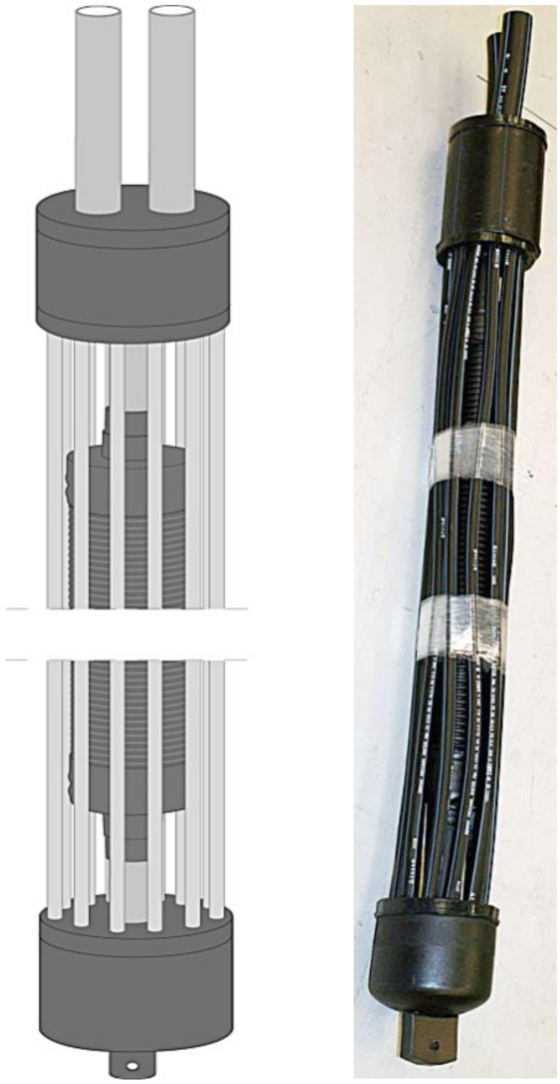
Thermal Response Test (TRT)

A thermal response test (TRT) is a procedure that is carried out in order to measure the heat transfer performance between the fluid in the GHEX (Ground Heat Exchanger) and the ground. The TRT is performed to make a cost effective BTES (Borehole Thermal Energy System) design.

The heat transfer performance can be divided in the thermal performance in the ground and the thermal performance in the borehole. Whereas it is difficult to influence ground thermal conductivity it is on the other hand easy to influence the thermal performance for the borehole by the GHEX (Ground Heat Exchangers) design and the material in the borehole.

Typical heat transfer rates in a GSHP (Ground Source Heat Pump) installation differ from 30–50 W/m, but higher rates as 100 W/m can be realized if solar collectors are used to charge the bore hole with heat that is going to be seasonal stored in the ground.

As part of the MESSIB project, a Thermal Response Test has been performed on two prototypes and the measured Rb values compared with a single and double U-loop for different brine flows. The results have proven that the TIL-GHEX offers considerably lower Rb than single and double U-loop. The TIL-GHEX has shown borehole thermal resistance around 0.02 K/Wm (dependant on the flow rate) while traditional U-collectors show thermal resistance in the range of 0.04 K/Wm (turbulent flow) and up to 0.07 K/Wm (laminar flow). The TIL-GHEX performs in particular better at laminar flow rates. The reason to that is that U-loops with large hydraulic diameters have to operate in turbulent flow regime to perform optimally.



Uponor TIL-GHEX.

Demonstration Projects

The MESSIB project demonstrates concept and solution of the project at three locations; one is a single-family like house in Greece. The other demonstrators which monitor the performance of the Uponor GHEX as a part of embedded system are located in Freiburg /Germany and Paterna/Spain.

Furthermore, the TIL-GHEX has currently been installed at a number of demonstration projects throughout Europe, including Freiburg in Germany, Virsbo in Sweden and the new office building project Plaza Loiste in Vantaa, Helsinki, Finland. The performance of the installations will be monitored for future improvement and optimization of the TIL-GEX and its interface to the integral building energy system.

Conclusion and Perspectives

Sustainable heating and cooling technologies for buildings is key to reduce the overall energy consumption in the construction sector and further integrate renewable energy sources. Improved thermal energy storage technology plays a vital role for balancing the fluctuations in supply and demand. Reliable storage systems for short as well as long term are hence essential for efficient energy systems that contribute positively to a sustainable construction development.

Being part of the MESSIB project has allowed Uponor to develop a co-axial TIL-GHEX ground collector and store system with proven superior thermal performance. The developed products and systems are already being installed within commercial projects which form a good basis for further improvements and commercialisation of efficient ground energy storage systems.

For further information please visit www.messib.eu.

Improved energy efficiency of air cooled chillers

In these last 10 years awareness in energy saving has continuously increased in both industrial and HVAC applications, we strive to regulate the electrical consumption of cooling equipment using the most effective efficient techniques. In the refrigeration and heat pump sectors increasingly European standard and directives are now applied to the appropriate and proper use of materials, innovation and in the application of new technologies to improve refrigeration system efficiencies.

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HVAC designs for Data Centre – Total Load 2.6 MW

In the refrigeration and air conditioning sector continuous attempts are made to reduce the energy consumption of all systems by improving the management of cooling power, optimizing the use of water-glycol flow and providing greater temperature accuracy. Recent research has developed the use of environmentally friendly refrigerants with lower ambient impact and excellent thermal performances. However, large refrigerant equipment still has very high power requirements, especially those demanded from very large air or water cooled chillers with screw compressors. The utilization of screw compressors is very high amongst large capacity chillers (>300 kW) and therefore the optimization of partial load performance, which is a condition present in almost all refrigeration plants at various stages throughout the year, is the goal prefixed by Hitema. A modern and intelligent technology is to control the large power demands of screw compressors with the frequency control network, using inverter electronic devices.

Advantages offered with the Inverter Technology

An inverter (VDF) is an electrical device acting on the variation of voltage and frequency. The inverter uses the line alternate voltage (a.c.) to produce a direct voltage (Diode Bridge - d.c.). From this direct voltage an alternate voltage is regenerated (PWM technique) with a frequency f between 0 and f_{max} (maximum frequency) and voltage $V<V_{net}$ (electric net voltage).

Inverters are widely used in film-polyester capacitor configuration, which is similar technique used on photovoltaic plants. The absence of electrolytic materials avoids the early aging due to the temperature, currents and stocking periods. The current distortion THDI is much lower than is electrolytic capacitors since the equivalent electrical capacity is lower. Moreover the compactness and longevity of inverters above film capacitors is also a consequence of superior effectiveness of cooling directly with liquid refrigerant line. When the frequency increases the number of compressor revolution increases linearly. As frequency increases compressors r.p.m. increases and as frequency decreases compressor r.p.m decreases. The application frequency range was widened between 30 Hz to 130 Hz.

Main advantages are:

- The starting current is effectively equal to 0, as current is directly proportional to frequency, the inverter starts the screw compressor with void frequency and it causes an absorption equal to 0.
- Cooling power can increase up to 20% above the optimal cooling power referred at 50 Hz, this is because the screw compressor can rotate with higher gears reaching higher frequencies up to 130 Hz.
- Higher operating flexibility due to large range of control (from 16% to 100%, widest modulation range on the market) and higher power density.
- Reduced electrical consumption at partial load between 30 Hz and 50 Hz compared to a standard screw compressor with a slide valve capacity control. This results in a measured absorbed power being reduced by up to 15%.
- Superior control of water outlet temperature exhibiting less fluctuation around the set point temperature. Typically tolerances of around +/- 0.5°C are possible.

- Reduced mechanical compressors wear, as the screw will rotate for most of year with reduced r.p.m. (higher MTBF).
- Inverter technology with screw compressor variable Vi, using automatic control of Vi the performances of chiller increase.

Performance of a Hitema chiller with compressors driven by inverter

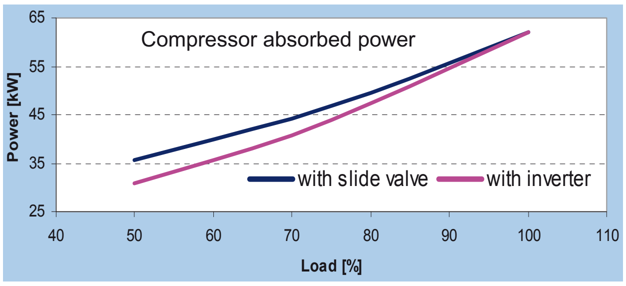


Figure 1. Comparison of performance of chillers.

Figure 1 illustrates the first important point showing lower absorbed power of the screw compressor when installed with an inverter, compared against a standard screw compressor with a slide valve. Chiller with inverter screw compressors are more versatile and highly efficient specialists used in chillers for air conditioning systems and industrial process cooling.

With a slide valve the gas flow control is less accurate than the inverter controlled counterpart. With a standard compressor the capacity steps are static and prefixed (eg, 100%, 75%, 50% and 25%). With the inverter solution, the screw revolution decreases proportionally and the gas flow is modulated linearly.

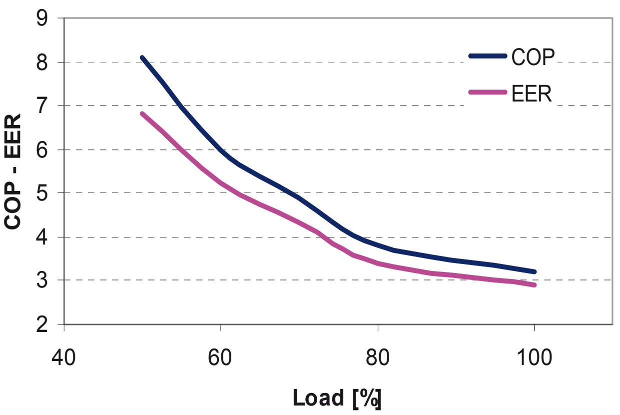


Figure 2. Performance for air cooled chiller.

Figure 2 illustrates the real data performance for air cooled chiller. The COP is the ratio between cooling capacity and the compressor absorbed power input. The EER is the relationship between the cooling capacity of chiller and the total power consumption of the refrigeration unit (compressors + fans). If the cooling load decreases whilst the ambient temperature decreases, then the absorbed power of chiller decreases much more rapidly than the reduction in cooling capacity in a non-linear relationship.

These COP and EER values are very competitive with other available technologies (eg, centrifugal compressors) and COP values with inverter screw compressors can attain >8 and EER >7. This chart above refers to an air cooled chiller with R-134A refrigerant, with inlet water temperature of 12°C and outlet water temperature of 7°C. The graph illustrates the massively beneficial effect on the efficiency of the chiller unit as the ambient air temperature and the load on the chiller reduce from 100% load in a 35°C ambient (worse case), to a situation whereby the load on the chiller is 50% and the ambient temperature is 15°C. As can be clearly observed, the EER for the unit at 50% load in a 15°C ambient is over double (~7) the value compared to when at 100% load in a 35°C ambient temperature (~3). The thermal performances indicated demonstrate that this unit easily qualifies for Class A efficiency categorisation.

It is clearly important to know the ambient temperature, the water temperature and the maximum load during the year (month by month) in order to assess the real operating efficiency of chiller unit.

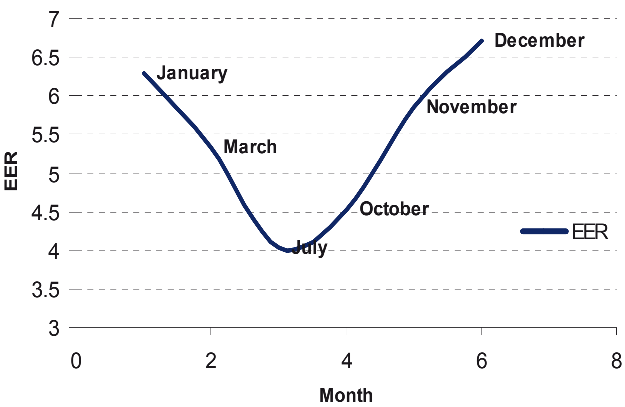


Figure 3. EER value of a chiller without free cooling.

Figure 3 shows the EER value trend of a chiller without free cooling when operating with a water outlet temperature of 5°C.

This chiller is designed for 680 kW at full load. During the warmer months of the season (June-August) the required load is 100%, whilst during the colder period (November-March), when ambient temperature is much lower, the chiller load is estimated between 50% and 60%. It is interesting to observe that the EER in the hotter months, during the worst demanding ambient conditions, has a minimum value of 4, whilst when the chiller load is around 60%, the EER values are typically between 6 and 7, much higher than a standard chiller. All these values refer to the maximum ambient temperature for each month, so these EER are considered as a *minimum*.

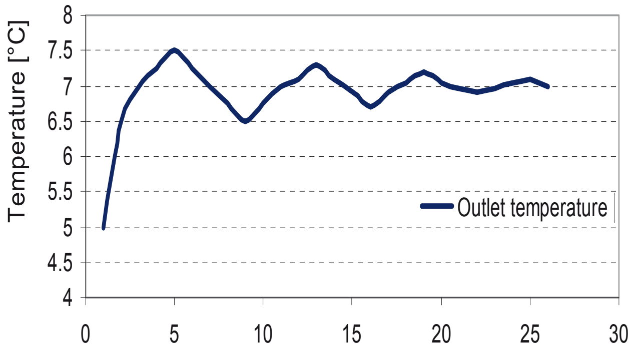


Figure 4. Outlet water temperature.

Figure 4 shows the outlet water temperature trend. Inverter control achieves much greater water temperature control than is possible with a standard screw compressor. It is evident that the water temperature fluctuation is only +/- 0.5°C deviation from the set point. Furthermore the set point value is established more rapidly than on standard a chiller.

In the European market the adopted index to classify chiller performance is E.S.E.E.R. (European Seasonal Energy Efficiency Ratio) and this is in accordance with E.E.C.C.A.C. proposal (Energy Efficiency and Certification of Central Air Conditioner). HITEMA inverter driven screw chillers has E.S.E.E.R. of over 5.

The formula used to calculated this is:

ESSER=
0.03 x EER(100%) + 0.33 x EER(75%) + 0.41 x EER(50%) + 0.23 x EER(25%)

The EER value (%) is the efficiency of chiller at 100%, 75%, 50%, 25% of load under various conditions in accordance with **Table1.**

For chillers with screw compressor installed with inverter control and variable Vi compressor, the increase achieved in the E.S.E.E.R. is around 15%.

Axial Fans for Condenser with inverter

Hitema also offer the use of inverters applicable to the standard axial fans. To control the volume of air circulated through the condenser in the air cooled chillers simple fan speed regulators to cut the phase applied to the fan motor are currently widely used. With this method, it is possible to decrease the rotation of the motor intervening directly on the supply voltage. However, with the use of inverters, which modulate the frequency from 20 to 50 Hz it is possible to reduce steadily the air flow and achieve improved condensing control.

Table 1. Weighting factors of part load efficiencies for calculating European Seasonal Energy Efficiency Ratio.

Water leaving temperature (°C)	7 (constant)			
Delta T full load (°C)	5			
Load (%)	100	75	50	25
Water Cooled Chiller				
Condenser water temperature (°C)	30	26	22	18
Air Cooled Chiller				
Condenser air temperature (°C)	35	30	25	20
Weight in ESEER (%)	3	33	41	23

Benefits obtained by the use of frequency variation with respect to voltage variation are the following:

- Reduced noise levels
  This is a key point when using axial fans for refrigeration in the air conditioning sector, as air cooled chillers are widely used in residential, external applications; when installed with fans operating from a variable frequency drive, significant noise reductions up to 6 dBA for the same chiller unit are possible (ISO3744).

- Lower energy consumption
  For low-medium speed (rpm) the frequency variation allows reduced power consumption. However the motor efficiency is completely utilized with all cooling load. A cut phase adjustable fan-motor has an efficiency ratio between 72–74% whereas the same motor with frequency driver has a performance ratio of 80%.

HITEMA uses another innovative application around the air fans, that it consists in the use of a special diffuser on top of the fans (**Figure 5**), that allows:

- Noise reduction of 6 dBA.
- Energy Saving of 22%.

Centrifugal process pump (2-4 poles) with Inverter

Hitema proposes the application of the inverter control on one or more centrifugal pumps, in order to obtain a non-dissipative regulation of power with the pump speed variation, depending on the heat load required. (**Figure 6 and Figure** 7)

Figure 5. Special diffuser for air fans.

Figure 6. Inverter driven double pump.

Figure 7. Electrical board with inverters for pumps.

Hence we obtain significant results in energy saving as you trace the real load energy requirements without any additional loss or consumption being incurred by the process.

To understand how the non-dissipative adjustment is able to act in this method, we can consider the operating curve of a centrifugal pump. (**Figure 8**)

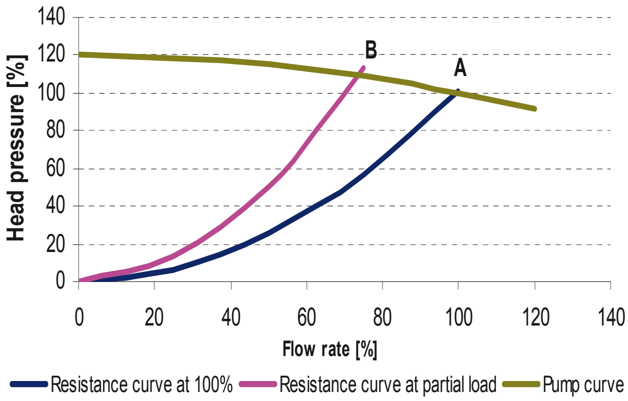


Figure 8. Operating curve of a centrifugal pump.

The intersection of the characteristic operating range for centrifugal pump with the typical flow-pressure curve can be used to identify the point of working regime (**point A** for 100% of load). If the load in the system requires a flow of 75% of the maximum by the regulation by the classic choke valve installed after the pump then an additional pressure drop is artificially introduces and the system must overcame a higher pressure drop (kPa or m.w.c.) than is actually required by load (**point B**). Furthermore by moving the operating flow point, the pump efficiency is also changed, which then introduces a further efficiency loss.

By adjusting inverter frequency instead, it follows the *real load demand* by altering the pump curve. (**Figure 9**). Varying the speed of the pump changes its actual operating curve, which will move vertically downwards and thus we reach into the new operating point (**point C**) without any adjustment valve introduction. This results in a real energy saving of 30%.

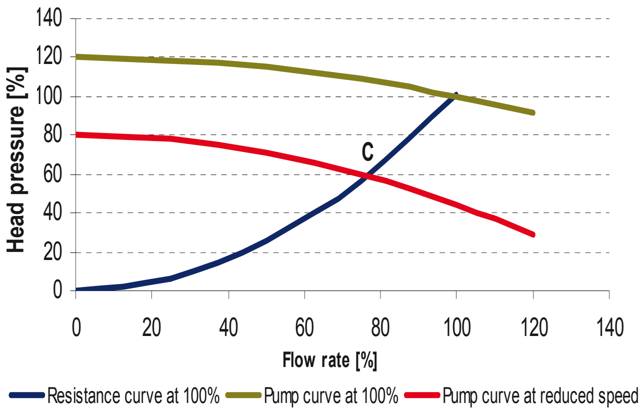


Figure 9. Operating curve with speed pump variation.

The process pumps when installed with an inverter can effectively have zero starting current if the water flow can be gradually increased up to the maximum flow, which again avoids potentially water hammer. The correct management of the inverter location completes the full system optimization.

Conclusion

Today there are many applications that require effective and innovative solutions to reduce the absorbed powers requirements of refrigeration hardware in process cooling industries, commercial air conditioning and data centres facilities. The optimum operation of refrigeration equipment at partial loads is especially significant in condition where the medium annual ambient air temperatures are between +5°C and +20°C, typical for the vast majority of European conditions. For even lower ambient temperatures the combination of inverter technology coupled with that of free-cooling, whereby chilled water can be produce using only fans energy, can be effectively used to produce chiller units with even greater efficiencies than previously considered possible. ∃

Eco design of energy related products – time for industry to wake up

The scope of Energy using product directive was expanded to all energy related products in 2009. The Eco-design directive allows the Commission to develop regulation – with minimum requirements and mandatory CE marking - for practically any product used in buildings.

Jorma Railio
Chair REHVA Technology and Research Committee
jorma.railio@gmail.com

The Eco-design directive does not set binding requirements on products by itself: it provides a framework for setting such requirements through implementing measures. The Commission prepares implementing measures only for products which have significant sales and trade in the EU – generally over 200 000 pieces per year - and a significant environmental impact and potential for improvement. The preparation of implementing measures includes several stages ending up in publishing the final regulation – meaning also that the requirements for products defined in the regulation are exactly the same in all EU Member States.

Industry and other stakeholders may follow the progress in all stages, and during the preparatory studies stakeholder meetings are arranged, in principle open to all. However, generally speaking, industry is not really well prepared - only a few companies put enough effort today to follow up, and very few forerunners (typically large international companies) influence actively. All others (SMEs, branch organizations, other stakeholders…) are either totally asleep, or struggle with lack of resources (expertise, money, language skill, patience…)

Process of preparation of regulations

Figure 1 shows the main phases of the preparations.

Figure 2 shows the phases in more detail, including also some features of the minimum duration of phases. The whole process takes 55 months as a minimum, but in practice the whole process can take up to 10 years.

Figure 1. Preparation of Eco-design regulations – the main phases. **1.** Working plan, **2.** Preparatory study – Stakeholder meetings, **3.** Draft regulation – Consultation forum, **4.** Regulatory Committee, **5.** Final regulation.

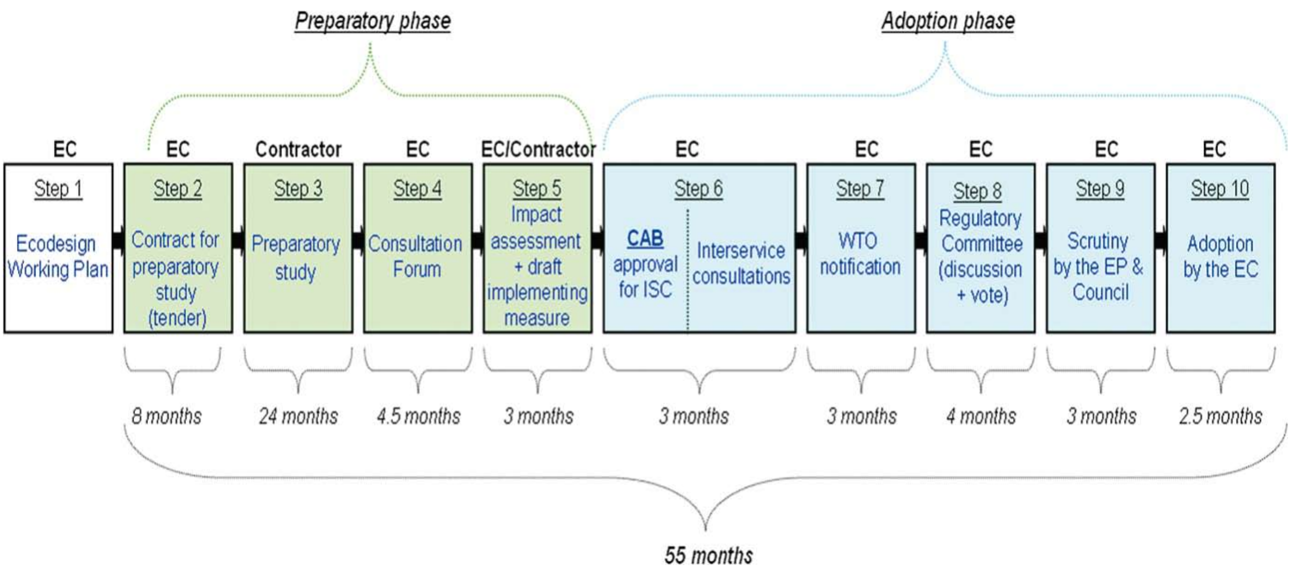


Figure 2. Minimum duration of different phases and steps of Eco-design process.

HVAC-related Eco-design regulations

Adopted HVAC related regulations

Implementing measures have been published and regulations have entered into force for several product groups, including (Regulations can be obtained from Ecodesign website -> Product groups page / Table at the bottom gives links to the regulations in all EU languages)

- Electrical motors - Commission Regulation (EC) No 640/2009
- Circulators - Commission Regulation (EC) No 641/2009
- Fans (125 W to 500 kW power input) - Commission Regulation (EU) No 327/2011
- Air conditioners and comfort fans - Commission Regulation (EU) No 206/2012

Regulations in preparation relevant to HVAC (studies completed)

ENER Lot 1 **Boilers** - The scope of this lot includes self-standing boilers. Technologies covered are fossil-fuel boilers, heat pumps and micro cogeneration up to electrical capacity of 50 W. This includes combination boilers providing heat for heating sanitary water.

The draft ecodesign requirements would be introduced gradually two and four years after entry into force of the regulation. Annex II of the proposal includes information requirements and minimum performance standards for seasonal space heating energy efficiency, water heating energy efficiency, sound power level and nitrogen oxide emissions.

> In the December issue of the journal, page 22, in Mr Saikkala- Grönroos interview it was estimated that the boiler regulations will be published in early 2014 – it should have been **early 2013**.

ENER Lot 2 **Water Heaters**. - The proposed requirements for water heaters, storage tanks, space and combination heaters include provisions for energy efficiency, storage volume, sound power level, nitrogen oxide emissions and product information.

ENER Lot 15 **Solid fuel boilers and fireplace**. - The scope of the proposed ecodesign requirements include solid fuel boiler space heaters and solid fuel boiler combination heaters ('boilers') ≤ 500 kW. Boiler combination heaters can be defined as boilers for space heating in combination with supply of heat to deliver hot drinking and sanitary water. They were not included in the preparatory study of lot 15, but have been included in the working document since no specific other lot covers this product type.

"ENTR Lot 6 – Air Conditioning and Ventilation Systems" –project was closed in July 2012. The "Document" page of the project*, now contains links to the complete final outcome of both "Ventilation" and "Air conditioning" parts of the study. **Ecodesign – Lot 20 and 21 for heating products** final reports are now available online for local heating (Lot 20)**, and for central heating products (Lot 21)***.

So, several product groups for heating, ventilation and air conditioning are subject to preparation of regulations. The difficulty is that a product with several functions can be subject to several regulations, e.g. one for heating, another or cooling, and a third one for ventilation.

For Ventilation units, a Working Document containing a draft regulation of ecodesign and labeling, was sent to the Member States in October 2012. The document is based on the "Ventilation" parts of **ENER Lot 10 and ENTR Lot 6**. One key issue there is that the borderline between "residential ventilation units" and "non-residential ventilation units" has now been defined. Units with fans of less than 125 W power input are regarded as "residential", and larger ones as "non-residential". The proposed regulation, however, gives the manufacturer the possibility to decide the category of the unit independently of the size. Labelling requirements are prepared for "residential ventilation" only, because energy labelling is primarily for consumer products.

2012 - 2014 working programme – other activities for the future

The Working Plan sets out an indicative list of product groups which are considered priorities for the adoption of implementing measures under the Ecodesign Directive.

List of "next" products subject to preparatory studies

European Commission, Directorate-General for Energy, launched in August 2012 a call for tenders with subject **framework contracts for the provision of preparatory studies, review studies and technical assistance**. This framework contract is divided into three lots. The first one deals with preparatory studies and related technical assistance on specific product groups listed in the ecodesign working plans adopted under the Ecodesign Directive. The products mentioned in the call, as priority product groups listed in the second and subsequent ecodesign working plans, include **steam boilers (<50 MW), smart appliances/meters, positive displacement pumps, heating controls and lighting controls/systems.** ƎƐ

* http://www.ecohvac.eu/documents.htm

** http://www.ecoheater.org/lot20/documents.php

*** http://www.ecoheater.org/lot21/documents.php

Substantial benefits of cogeneration to European economy

As Europe places increased importance on industry in its economic recovery strategy, Germany highlights a major role for CHP in a modern low carbon industrial base.

A new policy report endorsed by the German Ministry of Environment confirms that opportunities and possibilities offered by a massive backing of energy efficiency measures are much greater than expected. It finds that EU 2050 climate targets could be achieved through additional application of cogeneration to provide heat and power across the industrial base.

The report [1] "Contribution of Energy Efficiency Measures to Climate protection within the European Union to 2050" published on 19 November 2012 was commissioned by the German Ministry of Environment from the Fraunhofer Institute for Systems and Innovation Research ISI. It assesses the potential role of energy efficiency among options which will ensure that a shift to a sustainable European energy system still complies with the constraints imposed by competitiveness and security of supply.

In 2050 Europe's overall final energy demand could be reduced by 57 percent compared to the baseline with annual savings of 500 bn euros. The saving potential in industrial heat generation is primarily due to a further diffusion of CHP technology replacing units of separate heat and electricity generation as well as to efficiency improvements of separate and combined heat generation technologies and considerable efficiency improvements in space heating technologies. By 2030 and in the industrial sector alone, at least 9 Mtoe of savings result from CHP diffusion and 10 Mtoe from efficiency improvements in boiler and CHP technology. The total technical saving potential mounts up to 44 Mtoe by 2030 and to 95 Mtoe by 2050 compared to the baseline.

About cogeneration

Cogeneration (also known as CHP or Combined Heat and Power) is the simultaneous production of heat and electricity. 11% of Europe's electricity and associated heat requirements today are produced using this proven energy efficiency principle. The estimated growth potential for cogeneration is a further 110–120 GWe which will lead to an improved environment and greater economic competitiveness in Europe. Cogeneration units can be found in different sizes and applications: industry, households and tertiary sector and spans applications with capacities ranging from below 1 kw to hundreds of Megawatts. It is a highly efficient energy solution that delivers energy savings and substantial reductions in CO_2 emissions. When seriously supported, as in Denmark, CHP has the potential to increase the energy production and transformation system overall efficiency from a bare 33% (EU average) up to 65%. Realising the potential of cogeneration in Europe will contribute significantly to reaching the strategic climate and energy goals, such as security of supply, energy efficiency and reduction of emissions.

About COGEN Europe

COGEN Europe is the European association for the promotion of cogeneration. We represent 70 organisations which are National COGEN Associations, manufacturers, users, utilities and service companies. Currently around 100,000 Europeans are employed in the cogeneration sector. More info on www.cogeneurope.eu

[1] www.isi.fraunhofer.de/isi-en/service/presseinfos/2012/pri12-20_energy_demand_savings.phpc

National energy efficiency policies in EU: The view of 750 experts

Following an extensive on-line survey and interviews with about 100 EU energy efficiency experts, the Energy Efficiency Watch Survey report has now been published. The report tracks developments in each Member State. In all Member States, political will and the poor understanding of energy efficient are identified as key elements for successful energy efficiency policies.

The Energy Efficiency Watch 2 Project (EEW2) aims to facilitate the implementation of the Energy Services Directive and in general energy efficiency policies in the EU. It is co-funded by the Intelligent Energy Europe programme and coordinated by EUFORES.

One key activity of the EEW2 project was an extensive survey on the implementation results of the first National Energy Efficiency Action Plans (NEEAPs) in the 27 Member States. The aim of the survey was to learn from stakeholders, experts and relevant networks how they see the progress of energy efficiency policies and their implementation in different sectors since the first NEEAP in their own country.

Thus, the survey focuses on developments in the experts' own country, as interpreted by about 750 experts.

The survey report is the first in a series of reports from the project. In early 2013, 27 national reports profiling policy developments in each EU Member State will be published. The national reports follow a scientific analysis from the screening of all EU NEEAPs.

For more information:
www.eceee.org/news/News_2012/eew-survey-dec12
www.energy-efficiency-watch.org/
www.wsed.at/en/world-sustainable-energy-days/

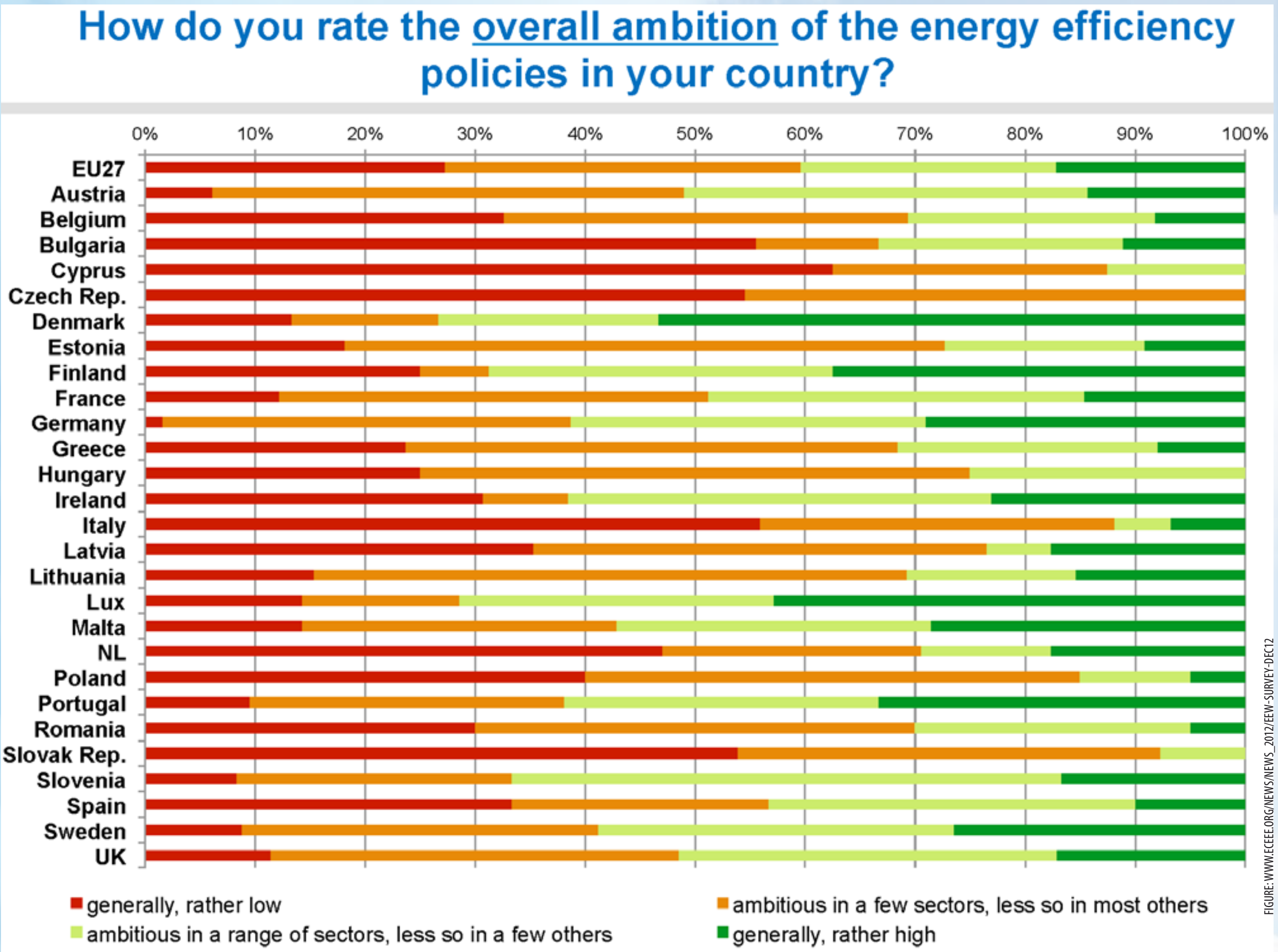


FIGURE: WWW.ECEEE.ORG/NEWS/NEWS_2012/EEW-SURVEY-DEC12

50th Anniversary for SWKI

REHVA congratulates SWKI (Schweizerischer Verein von Gebäudetechnik – Ingenieuren) with their 50th Anniversary on November 23, 2012.

SWKI
SICC
SITC

SWKI is REHVA's national member association from Switzerland. On that occasion REHVA's president prof. Dr.-Ing. Michael Schmidt handed over a small plaquette to express the warm relation between SWKI and REHVA.

Prof. Dr. Yury Tabunschikov was granted by VDI, the insignia of Corresponding Membership

Prof. Dr. Yury Tabunschikov was granted by VDI, the insignia of 'Corresponding Membership' during their executive board meeting on November 21, 2012.

This high VDI distinction is awarded only in exceptional circumstances. Prof. Tabunschikov – president of ABOK, REHVA's national representative from Russia – became his award amongst others for his outstanding research work in the field of constructional physics and building services, and his great contribution to come to international cooperation in our field. He did important translation work for VDI–guidelines, and REHVA dictionary. Prof. Tabunschikov is Head of the Engineering Department at the Moscow Architectural Institute (State Academy). REHVA is proud to have him on board as delegate of ABOK and congratulates him (and Marianna Brodatch) with this recognition.

Prof. Tabunschikov (left) receives VDI–Corresponding Membership, from prof. Dr.-Ing. habil. Bruno O. Braun, president VDI.

SCANVAC Prize 2012 to Jørn Simonsen

SCANVAC Prize 2012 was awarded unanimously by the jury to Mr Jørn Simonsen from DANVAC.

There was unanimous agreement between the four presidents of the Northern HVAC societies, that Mr Jørn Simonsen, through his tireless and outstanding work in the Danish and international HVAC industry, has contributed greatly to the HVAC industry and to the indoor environment field in general. The prize committee stated that the tribute was being paid to "A man who has made a difference".

Jørn Simonsen graduated from Technical University of Denmark in 1970 with a Master's Degree in Engineering, specializing in indoor environment. Immediately after his studies he was offered a job as a project engineer in the Danish consulting engineering firm Carl Bro.

In 1988 Jørn Simonsen joined Danvak, the Danish Society of Heating, Ventilation and Air Conditioning, as a member of the board of directors. After only two years he was elected chairman of the board and subsequently made a substantial difference to Danvak.

It was during this chairmanship that Jørn Simonsen and Danvak succeeded in reviving the informal HVAC exhibitions that were formerly held every second year.

In 1999 Jørn Simonsen became chairman of IDA HVAC, the professional HVAC network of the Danish Society of Engineers, and in 2003 he was again elected chairman of Danvak.

Roadmaps for Poland, Romania and Bulgaria towards nZEBs

The Building Performance Institute Europe (BPIE) has researched and developed an ambitious roadmap for Poland, Romania and Bulgaria which will help the country progress towards the implementation of nearly Zero-Energy Buildings and dramatically reduce the national level of energy consumption and related carbon emissions. BPIE research recommends a holistic policy approach which can deliver on energy, climate and economic goals.

European legislation on buildings (EPBD) and energy efficiency (EED) requires European member states to develop strategies on how to progressively transform their national building stocks into an energy performing and climate neutral built environment. Very low or 'nearly Zero-Energy Buildings' will become mandatory for all new constructions from 2020 onwards. To facilitate this process and to demonstrate the technical and economic feasibility of the nearly zero-energy standard, BPIE has undertaken a technical and economic analysis of the situation in three Central and Eastern EU countries - Poland, Romania and Bulgaria - and developed holistic implementation plan for each.

By 2013, EU member states are required to present to the EU Commission their national definitions of nearly Zero-Energy Buildings together with implementation plans towards more energy performing and almost CO_2 neutral new constructions. These national plans need to reflect the national understanding of nearly Zero-Energy Buildings, in line with local climate, economic and cultural conditions, including strategies and policies for specific building categories.

The studies build on the previous BPIE report Principles for nearly Zero-Energy Buildings and evaluate through simulations whether the assumptions made earlier hold true for Romania, Poland and Bulgaria. The report entitled 'Implementing nearly Zero-Energy Buildings, Towards a national definition and roadmap' combines a technical and economic analysis, based on specific national building data, economic conditions and existing policies. Different technological solutions - using variants of improved thermal insulation, energy efficient equipment for heating, cooling, ventilation and hot water and considering renewable energy generation - were simulated for improving the energy performance of offices, single-and multi-family houses. The costs were set in relation to the actual practice in construction in the country. Based on the simulation results, BPIE proposes a concrete national definition for nZEB for the defined building categories, as well as policy implementation roadmaps towards 2020, when all new constructions need to be nearly Zero-Energy buildings.

More information at www.bpie.eu

Sustainable Energy Week

The next edition of the European Union Sustainable Energy Week (EUSEW) will take place from 24 to 28 June 2013. Dates and procedures for organising an Energy Day in 2013 will be provided shortly. Meanwhile, we are very pleased to announce the opening of the Sustainable Energy Europe Awards and the ManagEnergy Local Energy Action Award.

EU Sustainable Energy Week (EUSEW) is a core activity of the Sustainable Energy Europe Campaign. Every year hundreds of organisations and individuals participate in the EUSEW.

Through bottom-up efforts, organisers of EUSEW Energy Days, events and activities connect directly with citizens and energy stakeholders at the local, regional and national levels. The combined results of EUSEW efforts are helping Europe reach its energy goals.

SUSTAINABLE ENERGY WEEK 24 - 28 JUNE 2013

managenergy

Calling for best-in-class sustainable energy projects - 2013 Sustainable Energy Europe & ManagEnergy awards - The European Commission invites all sustainable energy actors to submit their projects for the Sustainable Energy Europe Awards and ManagEnergy Local Energy Action Award.

Share your accomplishments and show how they have contributed to a more sustainable Europe. We look forward to receiving your application.

More information at www.eusew.eu

Progress with Ecodesign regulations for air conditioning and ventilation

The third and final stakeholder meeting of this product group (ENTR Lot 6) was held in Brussels in spring 2012. The presentations and a lot of new background documents, and now also the minutes of the final stakeholder meeting are available at www.ecohvac.eu/index.html - for the slides from the meeting, go to www.ecohvac.eu/meetings.htm.

Stakeholder comments on Ecodesign Study: Air conditioning and ventilation systems (ENTR Lot 6) are also available. The summary of comments (64 pages) shows that the industry is extremely interested in the topic and follow the preparation of the regulations closely.

The products which are included in the preparatory study are

1. Air conditioners
   - Package air conditioner [air-to-air > 12 kW, water-to-air, evaporatively cooled]
   - Split and multi split air conditioners [air-to-air > 12 kW, water-to-air, evaporatively cooled]
   - VRF (Variable Refrigerant flow) systems (a split system where the expansion of the
   - refrigeration occurs in the indoor units and not in the outdoor unit) [air-to-air > 12 kW,
   - water-to-air, evaporatively cooled]
2. Chillers for air conditioning applications [air-to-water, water-to-water, evaporatively cooled, condenserless]
3. Air conditioning condensing units [air-to-water, water-to-water, evaporatively cooled]
4. Terminal units to extract heat from the space to be conditioned
   - Fan coils
5. Heat rejection units means from the cooling system
   - Dry coolers
   - Evaporatively cooled liquid coolers
   - Cooling towers

The report includes detailed information on the market of the included products and the predicted increase in the total power and energy use.

Read more at **www.ecohvac.eu**: Sustainable Industrial Policy – Building on the Ecodesign Directive – Energy-Using Product, Air conditioning products, Lot 6, Final report of Task 1, July 2012

Koos Mast passed away just a few days after his 70th birthday

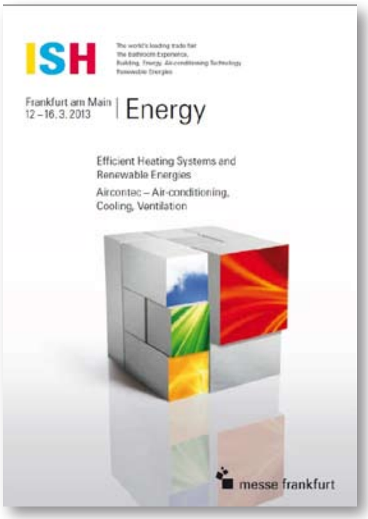
In Memoriam

On Friday 14 December 2012, **J.G. (Koos) Mast** MSc., Knight in the Order of Orange-Nassau, passed away just a few days after his 70th birthday. Koos was a very active and engaged person within both REHVA and our Dutch member association TVVL. He was President of the Dutch Society for Building Services (1997–2004). Subsequently he was TVVL's delegate to REHVA for many years. He was an Honorary Fellow of our federation, Chair of the REHVA Region One Group (2007–2011). He always expressed a strong positive influence on others, especially the youngsters in his environment. Koos was a real European in that respect, he was a sincere believer in developing communication between professional (HVAC) engineers all over Europe, he was especially proud of being elected a corresponding member of VDI, the German Engineering Institute, He was one of the founders of the 'REHVA Dictionary, our glossary in 15 languages with over 12 000 terms. Koos was President of TVVL's organizing committee for the "REHVA Annual Meeting 2009, Amsterdam". He was awarded honorary fellowships of TVVL and REHVA. His consultancy firm, Smits van Burgst - The Netherlands, was REHVA's first Dutch supporter.

We all wish Lies Mast and her family the strength to overcome their great loss. Koos will be sadly missed by all his friends in TVVL and the whole REHVA community. He was a real gentleman, a true friend and a real family-man, in every respect.

The next ISH on March 12–16, 2013 at Messe Frankfurt

ISH – The World's Leading Trade Fair for The Bathroom Experience, Building Services, Energy, Air Conditioning Technology and Renewable Energies – is the world's biggest exhibition for the combination of water and energy. With everything from sustainable sanitation solutions, innovative bathroom design and energy efficient heating technologies combined with renewable energies to environmentally friendly air-conditioning, cooling and ventilation technology, the world's leading trade fair covers all aspects of future-oriented building solutions in both horizontal and vertical terms.



- Top Themes ISH Energy in 2013 are:
- Efficient heating systems for gas and oil
- Systems utilising ambient and geothermal heat
- Heating systems utilising wood
- Thermal systems for the utilisation of solar energy
- Electricity-generating heating systems
- Large-scale combustion systems, process heat
- Energy-efficient ventilation and air-conditioning technology
- Energy-efficient room air conditioners and heat pumps
- Energy efficiency and comfort in residential buildings
- High-end ventilation and air-conditioning technology

More information at http://ish.messefrankfurt.com

REHVA Seminar during ISH in Frankfurt

REHVA will organise a Seminar during ISH on Thursday 14 March 2013. The topic will be school ventilation. Please visit www.rehva.eu for more information.

REHVA – ES-SO Guidebook Solar Shading is now available in five languages

In the authoritative series of REHVA Guidebooks, number 12 was published in 2011 under the title Solar Shading: How to Integrate Solar Shading in Sustainable Buildings. The content of the book has been contributed by ES-SO. This book, available in its original version in REHVA's bookshop (www.rehva.eu) has meanwhile been translated in several languages and is now also available in French, Swedish, Finnish and Portuguese. National ES-SO members have worked on the translations, together with the REHVA members of each country. The books are for sale via the various webshops of the ES-SO members (www.es-so.eu) or via REHVA. The book is a great asset for educational purposes – and for our own members, of course. More translations are in the pipeline.

Portuguese Solar Shading

Finnish Solar Shading

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Air Heating and Cooling Coils Using Water & Software FRTCOILS V.2
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Indoor environment in the focus of the 10th Ventilation Conference in Paris

Guangyu Cao and Aimo Taipale
VTT Technical Research Centre of Finland

The 10th International Conference of Industrial Ventilation - Ventilation 2012 took place during 17 - 19.9.2012 in Paris, France. The Ventilation congress organised every 3rd year.

Ventilation 2012 Congress in numbers:

- 397 registered participants
- 25 countries from all 4 continents
- 119 abstracts in the abstract book
- 69 papers in presented in 18 sessions

In addition, totally 7 keynotes and 2 workshops were organized during the two and half days. Seven keynote speeches were presented with regards to health, air distribution, noise, design principles, energy efficiency, occupational risk, ventilation control technologies. Two workshops are: Improving the effectiveness of Local Exhaust Ventilation in the workplace and On-site measurements of ventilation air flow rates. The structure of topics in the conference is illustrated in **Figure 1**. President of REHVA prof **Michael Schmidt** made a keynote presentation "Energy efficient office buildings" at the conference.

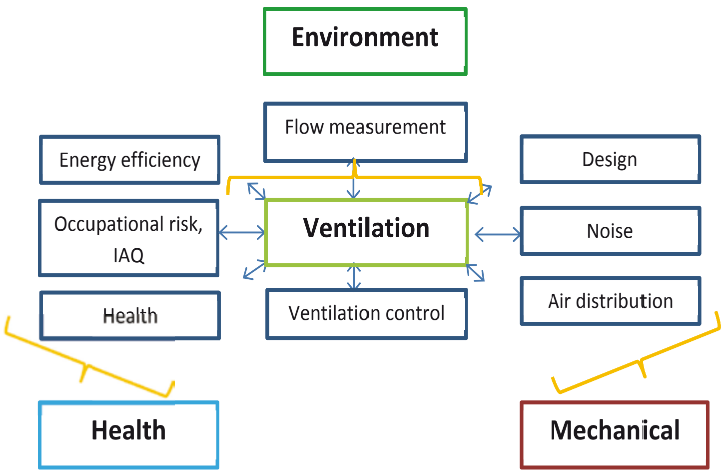


Figure 1. Main topics in Ventilation 2012 Conference.

Ventilation and health

Regarding health, Dr. **Pawel Wargocki** presented the results of one study regarding the effect of ventilation rate on health in homes. In addition, Mr. **Otto Hänninen** and Wargocki also introduced an EU project HEALTHVENT project, which is aiming at developing health-based ventilation guidelines in Europe. **Figure 2** shows the results of studies on the ventilation and health risks in homes, which suggest that increased ventilation rates, also demonstrated reduced concentration of CO_2, generally reduce health problems; only in few cases no effect or reverse effect was observed. However, the study found that no specific ventilation system can be recommended to provide minimum ventilation rates. Series of studies on ventilation and health in buildings with different ventilation systems would be desirable. In the future the emphasis will be occupant´s exposure to harmful airborne impurities from both indoor and outdoor sources.

The keynote presentation by **Gerhard Kasper** concentrated on occupational health risk caused by nanoparticles in the workplaces. One big question in this area is the size of particles relevant to health issues. Nanoparticles tend to agglomerate when released in the air forming bigger particles, which still might have the nanoparticle properties related to health issues. This agglomerated particle size is also close to MPPS (Most Penetrating Particle Size) which is most difficult to filter with mechanical filters.

Ventilation rates

One study shows that minimum outdoor ventilation rates in the building regulations of the most EU countries were in the range of 5.6 - 11 L/s/person, except for Czech Republic and Slovenia (14 L/s/person) (C. Dimitroulopoulou, Ventilation 2012). The minimum rate in the regulation of the Nordic countries is 7 L/s/person.

Aerosols and air distribution

In the study of aerosols and air distribution, Prof. **Peter V. Nielsen** showed the effect of RH on the transmission of exhaled aerosols, which presented in **Figure 5**.

It reviews that the transmission of exhaled gaseous substances from one person to anther takes place both in a direct way and via the room air distribution. Displacement ventilation has a high ventilation index, but it is also possible to have stratified exhalations in the occupied zone because of the vertical temperature gradient. This effect may increase the cross-infection, and the system cannot be recommended. This study also shows personalized ventilation built into a hospital bed is a new interesting possibility which can be used to reduce the cross-infection problem without making separate rooms for each patient.

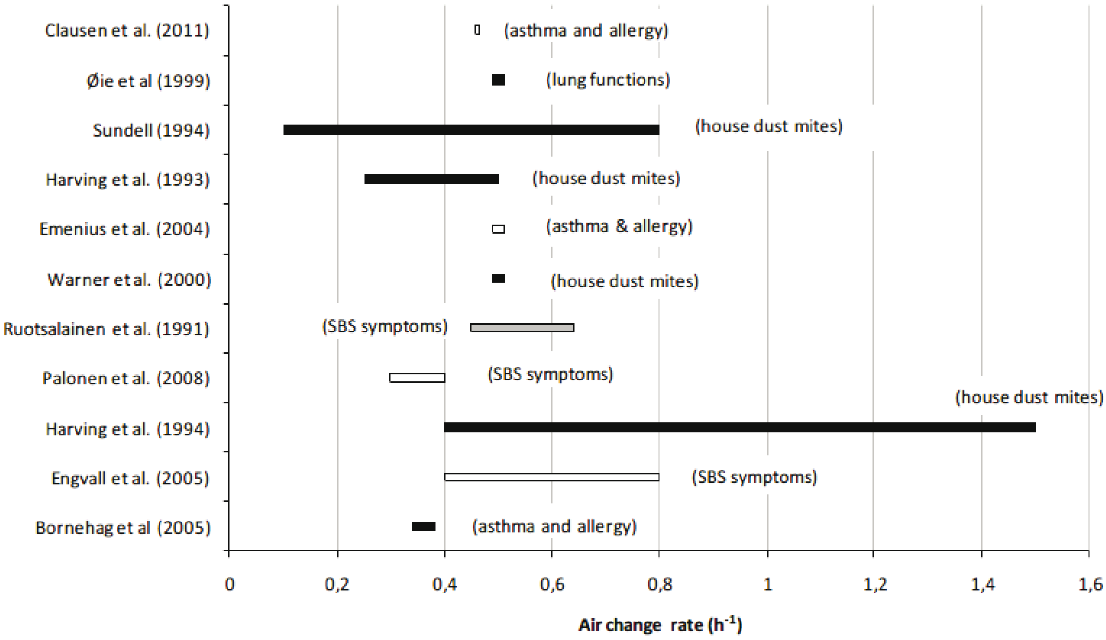


Figure 2. Ventilation rate in homes and health. (P. Wargocki, Ventilation 2012)

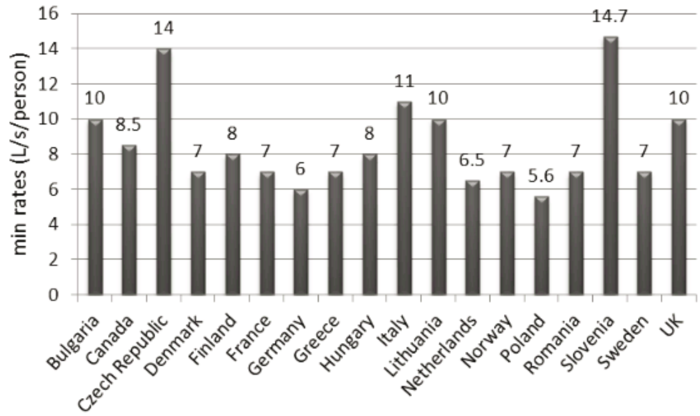


Figure 3. Minimum outdoor air supply in EU office buildings. (C. Dimitroulopoulu, Ventilation 2012)

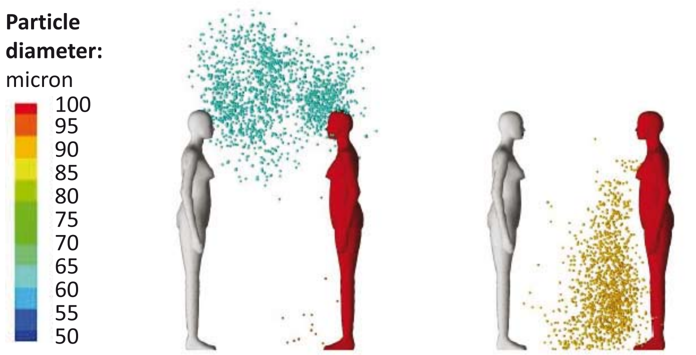


Figure 5. The left figure shows the exhalation of 100 µm droplets in 35% RH and the right side shows the same exhalation in surrounding air with a 95% RH after 12 sec of exhalation. (P. Nielsen, Ventilation 2012)

Conclusions

- Displacement ventilation has a high ventilation index, but it is also possible to have stratified exhalations in the occupied zone because of the vertical temperature gradient. (P. Nielsen, Ventilation 2012)
- The minimum outdoor ventilation rates in the building regulations of the most EU countries were in the range of 5.6 - 11 L/s/person, which is lower than recommended 25 L/s. (C. Dimitroulopoulu, Ventilation 2012)
- Majority of European buildings, 91% of population of EU-27 countries, reside in areas where one or more outdoor air pollutants exceed the WHO Guidelines for Air Quality. Larger benefits can be achieved by ensuring that the indoor air complies to the air quality guidelines. (O. Hänninen, Ventilation 2012)
- Ventilation/airflow rate is only the quantity of ventilation instead of quality, thus, the quality of airflow distribution should be paid more attention.
- Increasing ventilation rate alone could not ensure a better indoor air quality without taking into account the pattern of airflow distribution, filtration and the outdoor air quality. 3E

Zephir^3 by Clivet: air renewal and purification

at the centre of year round comfort and energy savings in the new and existing buildings

With Zephir^3 Clivet transformed the role of fresh air supply and purification within the HVAC system.

Zephir^3 is the innovative air renewal and purification system with active thermodynamic recovery system and **electronic filters**, which maintains fresh air flow whilst satisfying the full heating and cooling requirement. In this way it becomes the heart of the whole system, drastically minimizing chiller / boiler requirements and minimizing electrical infrastructure including standby generators.

The innovative **active thermal recovery** system recovers the maximum energy from the exhaust air all year round without any additional static pressure restrictions. Zephir^3 also employs high-efficiency compressor with DC inverter technology and hot gas free re-heating. The resultant system, which grants a **COP up to 6.5**, significantly out performs conventional fresh air systems.

Incorporating high efficiency **electronic filters** (H10 equivalent), Zephir^3 can remove smoke / dust and bacteria giving total purified air and creating the optimum fresh air condition, while **reducing cost for ventilation up to 30%**.

Zephir^3 allows a **reduction in the consumption of primary energy and CO_2 emissions by 50%** compared to conventional systems, contributing decisively to improve the class efficiency and value of the building.

The Zephir^3 industrialized standalone / fully packaged solution eliminates piping, insulation, and pump of the hydraulic circuits, **reducing the construction work by 80%**.

For all these characteristics Zephir^3 is the most flexible and energy efficient solution for all **commercial and industrial applications**, capable of working in total harmony with all terminal systems: **Fan Coils; DX; VRF/VRV; Radiant and chilled beams**.

For further information: Barbara Casagrande, tel. +39 0439/313235 – e-mail: **b.casagrande@clivet.it** - **www.clivet.com**

REHVA Guidebook No. 16 "**HVAC in Sustainable Office Buildings – A bridge between owners and engineers**" talks about the interaction of sustainability and Heating, ventilation and air–conditioning. HVAC technologies used in sustainable buildings are described. This book also provides a list of questions to be asked in various phrases of building's life time. Different case studies of sustainable office buildings are presented.

Window installation system for projecting windows

The illbruck Outside Wall Installation System is suitable for new buildings and renovation projects, for EIFS and brick facades. The system consists of six components: the PR007 Window Installation Frame and the PR009 Window Panel – both made of recycled materials – as well as the PR008 Insulation Wedge, TP652 illmod trioplex+, SP340 Adhesive and AT140 Primer. The frame is glued to the wall, which takes very little time because no mounting brackets are used. It's safe because it securely adheres to lightweight materials and has a tested load-bearing capacity of 200 kg per meter.

The frame, the insulation wedge and, where applicable, the panel create a kind of frame for the window, allowing for a secure, quick and standard sealing with illbruck TP652 illmod trioplex +.

Tests have proven that the illbruck system fulfills not only the airtightness require- ments of the upcoming EnEV 2012 regulation in line with the implementation of the EU building directive (will apply to all new buildings starting in 2019 or 2021), it is also the only glue-based solution for outside wall installation that has been certified by the ift Rosenheim. The results of the sound insulation tests were also excellent, because the installation system does not reduce the window's previously determined sound reduction index.

In addition, the window can be replaced later on without damaging the exterior facade.

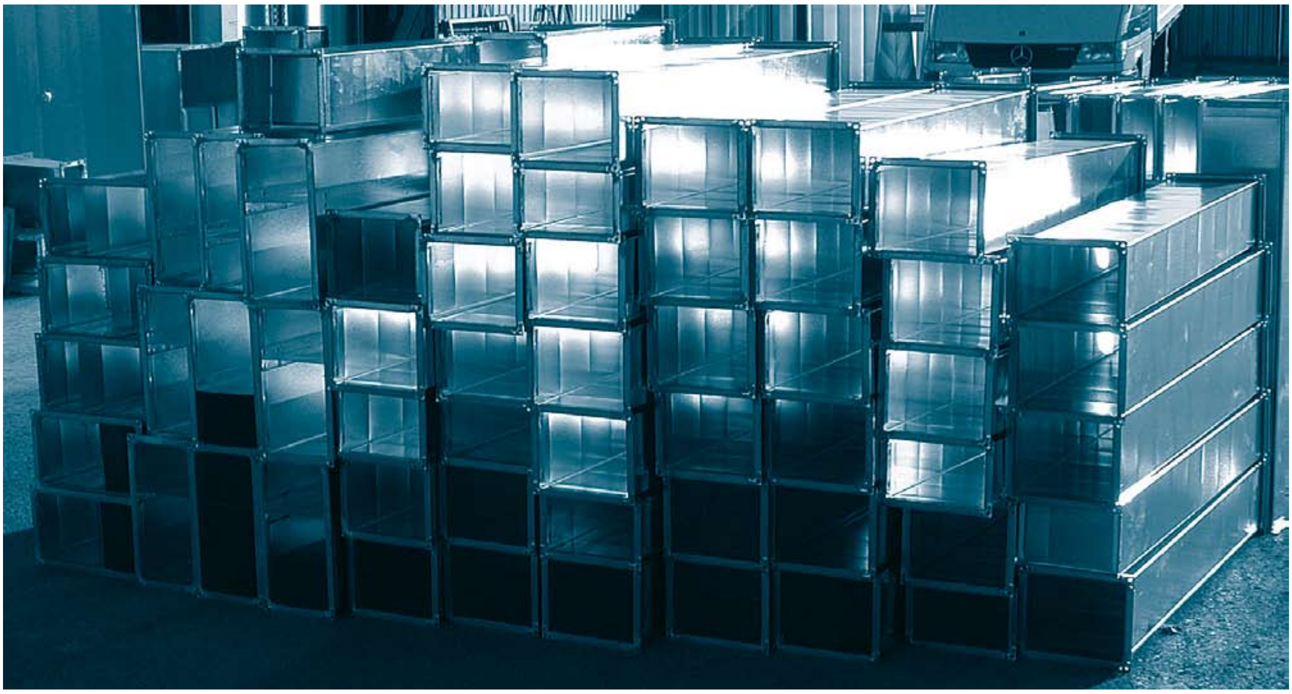
Key Benefits

- The window can be fitted into the structural opening and the system provides a cavity closer around the window
- The window can be replaced without the façade being damaged (renovation applications)
- Fulfills the airtightness requirements of the upcoming EnEV 2012 regulation in line with the implementation of the EU building
- System certification according to ift Guideline MO-01/1
- Quick and easy attachment and sealing of the window (TP652 illmod trioplex+ recommended)

Technical data

- Driving rain tight up to1 050 Pa following DIN EN 1027
- Airtight following DIN EN 12114 a < 0.1 $m^3/(mhdaPa^{2/3})$
- Pendulum impact test following DIN EN 13049 Class 5
- Load transfer for bonded system up to 200 kg/m
- Sound reduction following EN ISO 717-1 $R_w (C; C_{tr})$= 43 (–2:–5) dB

Further info see **www.tremco-illbruck.com**



The MEZ air duct profile complies with leak tightness classes C and D

To guarantee the quality of the air duct profiles (MEZ FLANGE SYSTEM) of MEZ-TECHNIK, compliance with leak tightness classes C and D was tested by an independent TÜV-certified testing laboratory according to EN 1507 at the end of 2009. The results went far beyond the required leak tightness values.

For decades, MEZ-TECHNIK GmbH has been supplying air duct builders in Germany and abroad with high-quality air duct profiles with and without injected sealant. Long before energy efficiency became the talk of the town, the ventilation specialist of Swabian Reutlingen recognised the trend towards increasingly higher requirements on the leak tightness and stability of ventilation ducts and the resulting energy savings. Ahead of all its competitors, MEZ-TECHNIK developed market-adapted air duct profiles with injected sealant, which it has continued to improve over the past decades. Only now – more than 30 years after the product innovation – have more and more competitors started to enter the market with imitation products and attempt to market them as an innovation.

The clear quality advance has been made possible not least due to decades of experience at MEZ-TECHNIK, as well as constant investments into research and development – and all that at absolutely competitive prices.

An often-underestimated factor for the leak tightness of the air duct systems is the stability of the frame profile used (cf. CCI 2005; "Materialschlacht um jeden Preis?" (The Battle for Materials at Any Price)). While many manufacturers have been using increasingly thinner sheet metal for the manufacturing of air duct profiles for cost reasons, MEZ-TECHNIK relies on constant material thickness in the interest of quality and its customers. On the one hand, this leads to a considerably higher stability of the air duct frame and thus to a higher leak tightness of the air duct system, while, on the other hand, the required change from System 20 to System 30 or from System 30 to System 40 is delayed, which reduces the material costs for customers and puts any extra costs for high material thicknesses into perspective.

In the next few years, the trend towards increasingly higher requirements on the leak tightness of ventilation systems will certainly intensify. To be able to guarantee leak tightness, it is important to use high-quality air duct profiles. Particular attention should also be paid to the material thickness of the air duct profiles since its influence on the overall efficiency of a plant is quite often underestimated.

info@mez-technik.de | www.mez-technik.de

Increased energy efficiency with TELLUS Climate system from Swegon

In the spring of 2012 Swegon launched its new multifunctional unit TELLUS on the international HVAC fairs Nordbygg and Mostra Convegno.

TELLUS is a complete, modular system product for the production of ventilation, heating, cooling and hot tap water. All these energies can be produced simultaneously or independently from each other, according to the actual demand.

TELLUS suits buildings between 600 m²–4 000m² due to its cooling capacity that ranges from ca. 25–82 kW, heating capacity between 12–60 kW and air volume between 1 000–16 000 m³/h. TELLUS can be used for regions with outdoor temperatures between +45°C and –20°C and can be placed indoors or outdoors.

Besides acclimatized supply air, TELLUS provides cooling water for comfort modules, chilled beams or fancoils and heating water for comfort modules, radiators or under floor heating.

Due to the built in controls and integrated design TELLUS can reach far greater energy efficiency than e.g. stand-alone air handling units or chillers. Especially effective energy use occurs in spring and autumn at outdoor temperatures between 5–15°C, when there is a simultaneous need for heating and cooling in the building. The smaller of the two energy demands is then provided for free. Swegon expects TELLUS to save an average of 30–50% of energy to acclimatize a building, in comparison to traditional systems.

The modular, compact design with all supply connections on one short side of the unit TELLUS allow a quick installation, the integrated controls make functional start-up and commissioning easy and the holistic approach makes maintenance more effective.

The TELLUS design includes a couple of new technologies that are patent pending, all for the purpose of saving energy with multiple recovery systems, both on air and water side. Also all temperatures and pressures are optimized in order to save fan, pump and compressor energy.

In the next REHVA Journal a more complete overview of Swegon TELLUS will be presented.

BlowerDoor Measuring Systems feature high and consistent accuracy

Since 2012 BlowerDoor GmbH in addition to the calibration of the DG-700 pressure gauges has also been offering the calibration of the BlowerDoor measuring fans using a calibration stand specifically developed according to German Industrial and European Standard DIN EN ISO 5801. Per ring (open fan and rings A-E) 3 values at 10%, 50%, and 90% of the respective flow-rate measuring range are each tested in the chamber test stand at a pressure differential of 50 Pa. The current environmental conditions, i.e. air pressure, temperature, and relative humidity, are calculated into the values measured in the testing chamber and those of the measuring fan according to manufacturer's indications. The structure of each ring set with five flow rings as "single-orifice plates" is particularly beneficial to the accuracy. The position of the pressure sensor as well as the geometry of the fan and the rings have been developed in order to create a stable and reproducible velocity profile that as far as possible is independent from the counter pressure (building pressure differential). Series of measurements have shown that BlowerDoor fans in longer use remain more accurate than what is usually required, within 1-2%. BlowerDoor GmbH according to manufacturer's indications recommends an annual adjustment and manufacturer's calibration of the pressure gauges and the calibration of BlowerDoor measuring fans every four years.

Technical Data (excerpt)

Minneapolis BlowerDoor Standard

BlowerDoor fan:

Capacity:
19 m^3/h – 7.200 m^3/h at a pressure differential of 50 Pa

Power supply: 220 – 240 Volt, 50 Hz, nominal output < 600 watts, max. power consumption 4.5 amperes

Measuring accuracy: With open fan/rings A – C (flow rate approx. 80 – 7.200 m^3/h) ± 4% of the mean, rings D + E (flow rate approx. 19 – 80 m^3/h) ± 5% of the mean or 1.7 m^3/h (whichever is greater)

Pressure gauge DG-700:

Measuring range: - 1,250 Pa to + 1,250 Pa

Display resolution: 0.1 Pa

Batteries: 6 AA (optional power supply 220 – 240 Volt)

Accuracy: ± 1% of reading or 0.15 Pa (whichever is greater)

For more information please contact
info@blowerdoor.de

Infitrometer from Retrotec

The Q5E Infiltrometer system uses the 2 hp fan and Retrotec's unique modular panel that looks professional, sets up quickly and allows for numerous testing configurations. Ideal for testing high-rise buildings one floor at a time or for multi-family and commercial buildings.

Retrotec is the world's leading manufacturer of blower door equipment, digital manometers, duct leakage test equipment, blower door testing software, and other tools for measuring building envelope performance.

See more at **http://retrotec.com/**

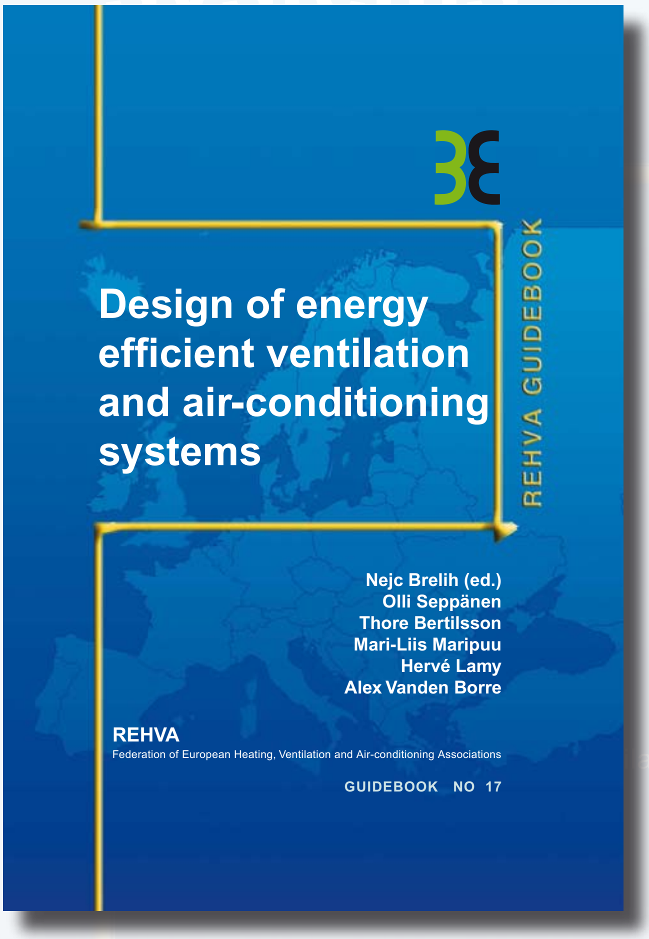
Review of the REHVA Guidebook No. 17 - Design of energy efficient ventilation and air conditioning

by Professor **Tim Dwyer**, Bartlett School of Graduate Studies, UCL, London | Originally published by the CIBSE Journal

www.cibsejournal.com

A new REHVA guide on energy efficient ventilation and air conditioning is a great starting point for designers and consultants wanting to get up to speed on the latest systems.

As REHVA heads into its 50th year, the Federation has expanded its series of guidebooks with the publication of the book Design of energy efficient ventilation and air conditioning systems, edited by Nejc Brelih, which marks the 17th booklet in the series. Despite the title, the modest 100 pages quickly establish that this is not a design manual but clearly a 'starting point', aimed at designers and consultants so that they can update their knowledge on contemporary, state-of-the-art commercial systems. Having provided a brief glossary of terminology, the book considers the state of the European building stock.



Contents of the REHVA Guidebook No. 17 - Design of energy efficient ventilation and air conditioning

1 Terminology
2 Energy and buildings in Europe
3 Indoor environmental quality
4 Air handling units
5 Energy efficient fans
6 Air filters
7 Air-to-air heat recovery systems
8 Demand controlled ventilation (DCV)
9 Design and balancing of ductwork
10 Chillers and heat pumps
11 Pumps & Hydronics
12 Electric motors and variable speed drives
13 Solar shading equipment
14 References

Although there are different climatic conditions, the common factor in Europe's buildings (of which about 29% is non-residential) is that a substantial proportion is more than 50 years' old, with nearly 60% having been constructed prior to 1975. The implication is that the principles conveyed in this book are potentially as important in the operation and refurbishment of existing buildings as they are for new build.

Providing some useful context, the proportion of built environment energy used in European non-residential buildings (with buildings consuming approximately 40% of total European energy consumption) matches their proportion at (just over) 30% of the total energy use. The guide laments that there is no detailed breakdown of the energy use in European non-residential buildings, but looks forward to the outcome of two ongoing projects – available to be reviewed at **ecbc-sa53.org** and **iservcmb.info** – which will provide this missing intelligence.

The importance of being able to examine – and benchmark – the nonresidential building stock with greater discrimination is highlighted by wide variations in electrical energy use recorded in buildings across Europe. This will, of course, be influenced by climate, but without proper differentiation it is almost impossible to assess relative performance of buildings, and to head towards the visionary expectation of net zero energy buildings laid out in the Energy Performance of Buildings Directive (EPBD).

Having set the scene, the succeeding 11 technical chapters provide a somewhat eclectic mix of topics related to the energy performance of building services systems. That is not to criticise, as it would be an unrealistic expectation that this pocket-sized volume would provide the breadth and the depth of a 'Faber and Kell' style textbook. The contributions appear well informed and the book was also independently peer reviewed.

And so turning to the technical chapters, (as listed in the box), these rightly open with the almost obligatory review of indoor environmental quality – the maintenance of which is the very reason for the existence of the industry represented by REHVA. The chapter successfully conveys the need to have a holistic understanding of the parameters that define a wholly appropriate internal environment, from the basics of temperature and the influence of clothing and activity, through to outlining the impact on the economic performance of the building. The layout of the subsequent chapters start with 'Recommendations in a nutshell', relating to the subject of each of the specific sections. The form of these naturally imply 'rules of thumb' that are bound to be keenly sought by students and developing practitioners alike and can, when properly informed, give a useful steer to the uninformed or forgetful.

The strength of these particular recommendations is that the reader can, and should, within a few hundred words, read the rationale and justification behind them. The description of the application of equipment associated with air handling units (AHUs), and particularly filters, fans, heat recovery units and pumps, is orientated towards minimising life cycle costs (LCC). There are some interesting examples comparing the effect that face velocity (the velocity that the air passes through an AHU) has on the LCC of AHUs, indicating the benefits of larger section AHUs and in conjunction with discussion on appropriate speed control of properly selected fans and pumps.

The inclusion of a dedicated chapter on motors and speed control is to be applauded in what otherwise may be thought of a 'mechanical services' publication – the brevity of the material is still capable of providing some important 'keynote' facts that may otherwise be marginalised. These core technical chapters provide a good grounding in the sensitivities of selection in centralised air conditioning and ventilation. The most extensive chapter covers on demand controlled ventilation (DCV), which contains some useful background on the benefits of using such systems, together with the practicalities of their impact on airflows into rooms and control.

Oddly, the book ends with a chapter on passive solar shading – no doubt an important influence on building performance – but the space may well have been used to cover areas conspicuous by their absence, including general room air distribution and decentralised systems, such as fan coils, chilled beams and hybrid embedded systems. Some of these are covered in other dedicated books in the series but, then again, so is solar shading. This guidebook provides a quick, well presented read of specific aspects of energy efficient centralised ventilation and air conditioning system technologies applied in commercial buildings. To cover such a potentially broad area, while including detailed discussions in such a condensed format, is challenging.

Design of energy efficient ventilation and air-conditioning systems is available at **www.rehva.eu**

Send information of your event to Ms Cynthia Depradel cd@rehva.eu

Events in 2013 - 2014

Conferences and seminars 2013

January 22	GEOTABS – Towards optimal design and control of geothermal heat pumps combined with Thermally Activated Building Systems in offices	Hannover, Germany	www.geotabs.eu/symposium-2013
January 26 – 30	ASHRAE 2013 Winter Conference	Dallas, Texas, USA	www.ashrae.org/membership--conferences/conferences/dallas-conference
February 8 – 9	ACRECONF	New Delhi, India	www.acreconf.org
February 27 – Mar 1	World Sustainable Energy Days – the WSED 2013	Wels, Austria	www.wsed.at
April 2 – 4	2nd IIR International Conference on Sustainability and the Cold Chain	Paris, France	www.iccc2013.com
April 10 – 11	European Biomass to Power	Krakow, Poland	www.wplgroup.com/aci/conferences/eu-ebp3.asp
April 11 – 12	CIBSE Technical Symposium 2013	Liverpool, UK	www.cibse.org
April 15 – 17	3rd International Conference in Microgeneration and Related Technologies in Buildings – Microgen III	Naples, Italy	www.microgen3.eu
April 24 – 26	SB13 Munich: Implementing Sustainability – Barriers and Chances	Munich, Germany	www.sb13-munich.com
May 9 – 11	5th International Conference on Amonia Refrigeration Technology	Ohrid, Macedonia	www.mf.edu.mk
May 27 – 28	36th Euroheat and Power Congress	Vienna Austria	www.ehpcongress.org
May 30 – 31	Energy Performance of Buildings and Related Facilities	Bucharest, Romania	www.aiiro.ro
June 3 – 8	eceee 2013 Summer Study on energy efficiency	Toulon/Hyere, France	www.eceee.org/summerstudy
June 7 – 8	The Latest Technology in Air Conditioning and Refrigeration Industry	Milan, Italy	www.centrogalileo.it/milano/CONGRESSODIMILANO2013english.html
June 16 – 19	11th REHVA world congress Clima 2013	Prague, Czech Republic	www.clima2013.org
June 19 – 21	Intersolar Europe 2013: Innovative Technologies and New Markets	Munich, Germany	www.intersolar.de
June 22 – 26	2013 ASHRAE Annual Conference	Denver, Colorado	www.ashrae.org/membership--conferences/conferences/ashrae-conferences/denver-2013
June 24 – 28	EU Sustainable Energy Week 2013 in Brussels	Brussels, Belgium	www.eusew.eu
June 26 – 28	Central Europe towards Sustainable Building Prague 2013	Prague, Czech Republic	www.cesb.cz/en
September 25 – 27	5th International Conference Solar Air-Conditioning	Germany	www.otti.eu
September 25 – 29	International Conference on Sustainable Building Restoration and Revitalisation	Shanghai, China	www.wta-conferences.org/conference/1869
October 3 – 4	CLIMAMED – VII Mediterranean Congress of Climatizacion	Istanbul, Turkey	www.climamed.org
October 15 – 16	European Heat Pump Summit	Nürnberg, Germany	www.hp-summit.de
October 15 – 18	IAQ 2013 – Environmental Health in Low Energy Buildings	Canada	www.ashrae.org/membership--conferences/conferences/ashrae-conferences/iaq-2013
October 16 – 18	Building Services for the Third Millenium	Sinaia, Romania	www.aiiro.ro
October 18 – 19	COGEN Europe Annual Conference & Dinner	Brussels, Belgium	www.cogeneurope.eu
October 19 – 21	ISHVAC	Xi'an, China	http://ishvac2013.org
October 20 – 21	Energy Efficiency & Behaviour	Helsinki, Finland	www.behave2012.info

Conferences and seminars 2014

May 13 – 15	11th IEA Heat Pump Conference 2014	Montreal, Canada	www.geo-exchange.ca/en/canada_to_host_the_11th_international_energy_agenc_nw211.php
August 31 – Sep 2	11th IIR-Gustav Lorentzen Conference on Natural Refrigerants – GL2014	Hangzhou, China	
October 18 – 19	CCHVAC Congress	China	

Exhibitions 2013

January 28 – 30	AHR Expo	Dallas, USA	www.ahrexpo.com
February 5 – 8	Aqua-Therm Russia 2013	Moscow, Russia	www.aquatherm-moscow.ru/en/home/
February 26 – Mar 1	Climatizacion	Madrid, Spain	www.ifema.es/web/ferias/climatizacion/default.html
February 27 – Mar 1	World Sustainable Energy Days – the WSED 2013	Wels, Austria	www.wsed.at
March 5 – 7	ecobuild 2013	London, UK	www.ecobuild.co.uk
March 7 – 9	ACREX 2013	Mumbai, India	www.ishrae.in
March 12 – 16	ISH Frankfurt	Frankfurt, Germany	www.ish.messefrankfurt.com
March 21 – 24	SODEX ANKARA 2013	Ankara, Turkey	www.sodexankara.com
April 8 – 10	ISH China & CIHE	Beijing, China	www.ishc-cihe.com
April 23 – 24	VVS Mässa Öresund – Trade Fair for Heating and Air Conditioning	Malmö, Sweden	www.easyfairs.com/fr/events_216/byggmaessa-oeresund-vvs-maessa-oeresund_23609/vvs-maessa-2013_24034/
November 4 – 8	Interclima+Elec	Paris, France	www.interclimaelec.com

Exhibitions 2014

April 1 – 4	NORDBYGG 2014	Stockholm, Sweden	www.nordbygg.se
March 18 – 21	MCE – Mostra Convegno Expocomfort 2014	Fiera Milano, Italy	www.mcexpocomfort.it
March 30 – Apr 4	Light + Building	Frankfurt, Germany	www.light-building.messefrankfurt.com
May 7 – 10	ISK – SODEX 2014	Istanbul, Turkey	www.hmsf.com
October 14 – 16	Chillventa 2014	Nuremberg, Germany	www.chillventa.de/en/
September 30 – Oct 3	Finnbuild 2014	Helsinki, Finland	www.finnbuild.fi

International Exhibition on Air Conditioning, Refrigeration & Building Services

ACREX INDIA 2013

7-8-9 MARCH 2013

Bombay Exhibition Centre, Goregaon (E), Mumbai

www.acrex.in

Dedicated to an eco-friendly **environment**

Highlights of the Exhibition

- Over 300 national and international companies participating
- 20,000 Trade Visitors
- Participation from 20 Countries
- Interactive Panel Discussion
- Seminars
- Awards of Excellence
- Students' Quiz

TECHNICAL WORKSHOPS

March 5th to 9th, 2013 | Hotel Hyatt Regency, Mumbai, India

Healthcare | Data Centers | Indoor Air Quality | Ventilation | Fire Security

Platinum Partner: Carrier (turn to the experts), United Technologies

Gold Partners: Blue Star (Breathe Easy), Bell & Gossett (a xylem brand)

Registration Desk Partner: AHRI Certified (Globally Recognized. Industry Respected.)

Silver Partners: Climaveneta, Eurovent Certification, Mitsubishi Electric (Changes for the Better, Air Conditioners), Pahwa (Bry-Air, DRI – Air is our address), Twiga (Insulating India), VTS

Knowledge Partners: Emerson Climate Technologies, Giacomini (Technology in Comfort), GMP Technical Solutions, iClean

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Endorsed by: ASHRAE – Shaping Tomorrow's Built Environment Today

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Supported by: REHVA, AMCA, Indian Green Building Council, RAMA (Refrigeration and Airconditioning Manufacturers' Association), ACRA, CCSI (Contamination Control Society of India), FSAI

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Best Wishes for a Healthy and Prosperous year 2013

The Editorial Board members, the REHVA Board Members, the Editor-in-Chief and the staff wish all the readers a happy and prosperous year 2013.